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ALIEN TERRESTRIAL ARTHROPODS OF EUROPE

Edited by Alain Roques, Marc Kenis, David Lees, Carlos Lopez-Vaamonde, Wolfgang Rabitsch, Jean-Yves Rasplus and David B. Roy

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EDITORIAL

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DAISIE and arthropod invasions in Europe

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A milestone in the knowledge of alien species in Europe has been achieved by the DAISIE (Delivering Alien Invasive Species Inventories for Europe) project. Through the Sixth Framework Programme of the European Union, DAISIE has delivered a major portal for information on biological invasions that is publicly available at http://www.europe-aliens.org. The rationale was to develop a pan-European inventory of invasive alien species by integrating existing databases, to describe patterns and evaluate trends in biological invasions in Europe, identify priority species and assess their ecological, economic and health risks and impacts. Although an on-going process, the foundation, scope, and technological architecture of DAISIE was established through a consortium of leading researchers of biological invasions in Europe from 19 institutions across 15 countries and delivered through the cooperation of experts in ecology and taxonomy from throughout Europe that in total amounted to 182 contributors. The inventory, accounts, and distribution maps today provide the first qualified reference system on invasive alien species for the European region. The information presents an outstanding resource to synthesise current knowledge and trends in biological invasions in Europe. The data will help identify the scale and spatial pattern of invasive alien species in Europe, understand the environmental, social, economic and other factors involved in invasions, and can be used as a framework for considering indicators for early warning.

A key component of DAISIE is *The European Alien Species Database*, an inventory of all alien species in Europe, and resulted from compiling and peer-reviewing national and regional lists of alien fungi, bryophytes, vascular plants, invertebrates, fish, amphibians, reptiles, birds and mammals. Data were collated for all 27 European Union member states (and separately for their significant island regions), other European states (Andorra, Iceland, Liechtenstein, Moldova, Monaco, Norway, the European part of Russia, Switzerland, Ukraine, former Yugoslavia states) and Israel. Marine lists are referenced to the appropriate political region with administrative responsibility. To have full coverage of the European marine area, the data for countries bordering the Mediterranean Sea in North African and Near East countries are included. By November 2008, records of 10,771 alien species, were included in the database, belonging to 4492 genera and 1267 families. Both species of exotic origin and species of European origin introduced in European regions outside their native range were considered. Plants are most represented accounting for 55% of all taxa (5789 species), terrestrial invertebrates 23% (2477 species), followed by vertebrates (6%), fungi (5%), molluscs (4%), Annelida (1%) and Rhodophyta (1%). In total, the database includes records of 45,211 introduction events to particular regions (plants: 28,093; terrestrial invertebrates: 11,776; aquatic marine species: 2777, terrestrial vertebrates: 1478; aquatic inland species: 1087). Due to unprecedentedly thorough assessment, DAISIE substantially improved the accuracy of estimates of alien species numbers derived from previous datasets.

The information accumulated by DAISIE has been summarized in the *Handbook of Alien Species in Europe* (DAISIE 2009), which contains analytical chapters on each taxonomic group, and fact sheets of the 100 most invasive alien species in Europe with distribution maps and images. The book also lists all alien species recorded, ranked taxonomically; this list can be used as a reference for future assessment of trends in biological invasions in Europe. The current volume "*Alien terrestrial arthropods of Europe*" largely follows the lead set by the *Handbook of Alien Species in Europe* but provides much needed detail on one of the largest and most complex taxonomic groups, the arthropods.

Unlike other groups of animals and plants, no checklist of alien terrestrial invertebrates was available in any of the European countries until the beginning of this century. Thus more than any other taxonomic group, creating an inventory of invasive alien arthropods in Europe proved to be a major challenge. Consequently, an estimate of the importance of terrestrial alien invertebrates at the European level remained impossible, largely due to the limited taxonomic knowledge regarding several major arthropod groups. As a result, the initial analyses in DAISIE were drawn from the most reliably studies group, the insects. Even with such a partial picture, the new evidence emphasised the need for more detailed assessment of alien arthropods. For example, the initial work in DAISIE has shown that approximately 90% of terrestrial insects having arrived into Europe unintentionally (75% associated with a commodity, 15% as stowaways). The highest numbers of insects occur in human-made habitats (ruderal, cultivated land, parks and gardens) and invasions are concentrated to these few highly invaded habitats. Not surprisingly insects are one of the taxonomic groups with the most species causing impacts in Europe, and most of these impacts are on the economic rather than environmental sectors. In this regard, *Alien terrestrial arthropods of Europe* extends the initial work in DAISIE and develops a clearer picture of arthropod invasions across a much larger taxonomic range than insects. This substantial work will set the benchmark for authoritative assessments of invasive terrestrial invertebrates.

Through DAISIE, Europe is today the continent with the most complete information on its alien biota. The continent has been working towards implementing an effective strategy on invasive alien species and DAISIE is considered as one of the major instruments towards achieving this goal. An internet-accessible knowledge base, such as DAISIE, can provide crucial information for the early detection, eradication, and containment of invasive aliens —which is most achievable for species that have just arrived. As a result of DAISIE, managers and policy-makers addressing the invasive alien species challenge can easily obtain data on which species are invasive or potentially invasive in particular habitats, and use this information in their planning efforts. Agencies responsible for pest control can quickly determine if a species of interest has been invasive elsewhere in Europe. Importers of new alien species can access data to make responsible business choices. Land managers can learn about control methods that have been useful in other areas, reducing the need to commit resources for experimentation and increasing the speed at which control efforts can begin. DAISIE is potentially a model for other continents which currently have much less detailed information on their alien biota.

References

DAISIE (2009) *Handbook of Alien Species in Europe*. Dordrecht: Springer.

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RESEARCH ARTICLE

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Introduction
Chapter 1

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Dispersal of organisms is among the most important conditions that has enabled the development of life on earth and the high diversity of species we encounter today. This natural process is guided by biogeographical barriers which subdivide the accessible space of the Earth into compartments: species are limited to islands, summits, lakes, or oceans and shorelines, mountain ridges or climate zones. Such natural boundaries reduce competition, create conditions for speciation, and form the basis for the evolutionary centre where a given species has originated. This species is then **native** (indigenous) to this area.

These natural biogeographical barriers have increasingly been overcome by human dispersal and humans now inhabit all parts of the world. This process of human dispersal started in Africa more than 100,000 years ago, and is an intrinsic part of human history. At first, this slow but continuous conquest was performed by walking, at the natural speed of humans, and was limited by the physical condition of individuals. The speed of movements increased in the last centuries and today, we can reach virtually any spot on earth by airplane within 24 h. The turning point was certainly, when sailing ships circumnavigated the world and connected continents. With such big carriers, mass transportation of materials, animals and plants over large distances was also possible.

Christopher Columbus was the second European in the New World (the first discovery of North America by the Vikings some 500 years earlier had no long-lasting consequence, other than the introduction of the North American bivalve *Mya arenaria* to Scandinavia in the 1200s (Petersen 1992), and with him the global race duel to connect all parts of the world faster and tighter began. Thus, the year 1492, when Columbus set foot on the first Caribbean island was the starting point of this self-accelerating process later called globalisation.

This process had serious consequences because man did not travel alone. His entourage comprised crop plants and domesticated animals and pets, including all the pests, pathogens and parasites which usually adhere to them. In other words: in the last 500 years hundreds and thousands of species have been spread worldwide both intentionally and unintentionally. Through this human aided spread the biogeographical barriers have become more and more permeable and more and more species are no longer restricted to their native areas.

Species living outside of their natural range and outside of their natural dispersal potential are **alien species**. Their presence in the new habitat is due to intentional or unintentional human activities and without this human support they would never have reached their new area. Thus, there is an important difference between natural dispersal of species that, e.g., allows Mediterranean species to spread north of the Alps because the summers are becoming warmer and man-mediated transport of American, African, Asian or Australian species which then suddenly show up in European harbours or airports and disperse into the hinterland. These last species are called **alien *to* Europe**. Obviously, species of European origin may also be translocated by man outside of their natural range, e.g. Mediterranean species to Northern Europe or species of continental Europe to Atlantic and Mediterranean islands. In this case, they are called **alien *in* Europe**. However, in many cases it appears highly difficult to disentangle the effect of human-mediated transport from that of natural dispersion when a native European species is suddenly found outside its range.

But why is it disadvantageous to increase the number of naturally occurring species (the native fauna and flora) by some alien species? In most (if not all) natural ecosystems the given set of species is the result of a long adaptation and co-evolution to the physical and biotic environment. The higher the natural biological diversity is, the greater the biotic resistance is against additional, foreign species. If ecosystems are disturbed (e.g. by fire, flooding or erosion) or are artificial ecosystems (such as agricultural habitats or urban areas), alien species have a much higher chance to establish.

An alien species will interact with resident species or the abiotic environment in a different manner than a native species and therefore such an additional species is usually neither an enrichment of the ecosystem nor any amelioration of a process. Alien species are usually somehow different from the resident species since they have evolved in a different environment. They may represent a new type of predator, they may have novel weapons, or they may have other new properties which may enable them to alter habitats or even ecosystem functioning. They can fill hitherto empty niches, they may change matter flux or impact energy flow. Such changes affect the resident species most often in a negative way and native species may become less common or even disappear. At this stage, the alien species impacts the invaded ecosystem and becomes an **invasive**

species. Usually the term "alien" is used in the sense of "not wanted here" but calling it invasive is a clearly negative attribute.

The consequences of an alien species can be manifold: Most obvious is direct competition with native species, an increasing abundance in the new environment until a complete replacement of native residents occurs. Alien species may be associated with pathogens and parasites or they are pathogens and parasites, which may transfer onto and affect a new host. If the new host is susceptible to the new pathogen or parasite, a strong reduction in the population of this native species will result or even local extinction is possible: The alien species has thus caused a loss of biodiversity.

Further consequences of an alien and invasive species may concern water flux, e.g. by increasing consumption or contamination. Matter flux (primarily carbon or nitrogen) may be influenced by an altered decomposition of plant litter and wood or via nitrogen-fixating symbionts.

Besides such environmental impacts many alien species cause enormous economic impacts or directly influence human or animal health. Many alien invertebrates, especially insects, cause great damage to agriculture and forestry. Many protozoans and "worms" are human parasites and many insects are vectors of bacteria and viruses which cause numerous serious diseases. Today, such super-pests are cosmopolitan but this term camouflages that in most parts of the world, where they occur today, they are alien and invasive species. In the case of humans and on a global scale, they cause millions of fatalities each year.

Not all alien species are invasive and it is in fact strange to observe some aliens for years and decades at a given location that show no signs of obvious spread. The process from the first introduction of an alien species into a new environment until aggressive invasiveness is characterised by several steps and an alien species may fail at each of these steps. After a first introduction, it is decisive if the new environment fits the need of this species. Usually, if the number of individuals is low, the species has a rather small chance of establishing reproducing populations. But the higher this number is or the longer the introduction process lasts, the better the chances are of the new species establishing. Establishment means survival and reproducing viable populations on the spot, which is called the lag phase. The next step is when the alien species produces a surplus reproduction which allows modest migration. In this period an alien species may adapt in some way to its new environment and this phase is often called bottleneck with a transition from the lag phase to the log phase. In the log phase, the alien species reaches more suitable habitats which allow a higher reproduction. By continuous population growth, the population pressure on adjacent areas is increased and impacts on the ecosystem also become evident and increase: now the alien has become invasive. Observing an alien in a non-invasive status does not mean that it will not become invasive (and thus can be tolerated as harmless), it rather means that it is not (yet) invasive but it could be just a matter of time until it becomes invasive. Changes in land use or climate can also enable previously harmless alien species to begin to spread uncontrollably and become invasive.

Roughly 50 years ago, the British ecologist Charles Elton published his *Ecology of invasions by animals and plants*, already then warning of the danger arising from alien and invasive species: "The whole matter goes far wider than any technological discussion of pest control, though many of the examples are taken from applied ecology. The real thing is that we are living in a period of the world's history when the mingling of thousands of kinds of organisms from different parts of the world is setting up terrific dislocations in nature. We are seeing huge changes in the natural population balance of the world" (Elton 1958). Elton was among the first to describe the typical pattern of an alien species establishment. That what he called "biological explosion" is today known as biological invasion (Nentwig 2008). He was also among the first to investigate why and how species were dispersed by human activities and he analysed even then the negative impacts of species in a new environment. He was among the first to ask how this could be prevented.

Astonishingly, the hazards provoked by alien species did not cause that much concern among scientists, nor did it attract public awareness as much as would have been expected (Hulme et al. 2009). However, the ultimate reason for the loss of more than 5% of the world GNP, one main reason for the loss of biodiversity, for millions of human deaths, and for the loss of more than 20% of the world's food production cannot be ignored.

Prevention has multiple faces leading from raising awareness in the public to better scientific knowledge and documentation. More regulations and guidelines must to be put into place and existing regulations must be applied more consequently and carefully. Further import of aliens should be avoided; current aliens should be confined, controlled and even eradicated. We must face this challenge through changes in world trade, adoption of regional strategies and regulations, improved national legislation and better administration, but also through improvements in general education and awareness and the improved spread of information through the media.

Science is also absolutely required in order to manage the problems that alien species may cause. How can they be detected and identified? What is their population development and habitat requirement? What is their impact in the invaded area? How can they be controlled, reduced, or eradicated? How can we predict which species that may become invasive and how can we manage the risks? For most alien species there are yet no answers to most of these questions. Even the seemingly simple question on the number of alien species in Europe could not been answered a few years ago.

Therefore, the European Commission, in its Sixth Framework Programme, launched a call for an inventory of alien invasive species. The successful application was awarded to a consortium of leading researchers of biological invasions in Europe, drawn from 19 institutions across 15 countries. The resulting project, DAISIE (Delivering Alien Invasive Species Inventories for Europe), was launched in February 2005 and ran for three years, until the end of January 2008.

The main objectives of DAISIE were (1) the creation of an inventory of all known alien species in the European terrestrial, freshwater and marine environments; (2) to describe the worst alien and invasive species in Europe and to describe their environmental, economic and health risks impacts; and (3) to compile a directory of experts on alien species. Since February 2008, the DAISIE information system is freely available at http://www.europe-aliens.org. In 2009 a condensed version of the DAISIE information system was published in a Handbook of Alien Species in Europe (DAISIE 2009).

Invertebrates, and among them arthropods, comprise the largest proportion of alien animals and are of pronounced importance, e.g. in agriculture, horticulture and forestry, the cultural environment and for human and animal health. Despite the far reaching and serious effects that alien invertebrate species have on biological diversity, health and society, knowledge of their effects and potential risks is still insufficient. This knowledge is crucial for managing the risks involved with the transfer of species both intentionally and unintentionally. Based on the expert knowledge of 78 scientists from 25 European countries, this book will present for the first time in a comprehensive way the alien arthropods having established in Europe, including detailed information on taxonomy, pathways, invaded habitats, impacts and trends. The book will focus on the 1590 terrestrial arthropod species presently identified as aliens *to* Europe. They will be presented by taxonomic rank. For each group, additional information will be provided about the species alien *in* Europe whenever the actual status of such species can be considered as ascertained with regard to the difficulties mentioned above. Moreover, the 80 most important alien invasive species are presented in factsheets in more detail in order to raise awareness and provide information upon which to base measures to prevent and control these species.

References

DAISIE (2009) *Handbook of alien species in Europe*. Dordrecht: Springer. 399 pp.

Elton CS (1958) The ecology of invasions by plants and animals. London: Methuen & Co. Ltd. 181 pp.

Hulme PE, Pyšek P, Nentwig W, Vilà M (2009) Will threat of biological invasions unite the European Union? *Science* 324: 40–41.

Nentwig W (Ed) (2008) *Biological Invasions. Ecological Studies* 193. Heidelberg: Springer. 441 pp.

Petersen KS, Rasmussen KL, Heinemeier J, Rud N (1992) Clams before Columbus? *Nature* 359: 679.

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Taxonomy, time and geographic patterns Chapter 2

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Abstract

A total of 1590 species of arthropods alien to Europe have already established on the continent, including 226 more or less cosmopolitan species of uncertain origin (cryptogenic). These alien species are dispersed across 33 taxonomic orders, including crustaceans, chilopods, diplopods, pauropods, Symphyla, mites, arachnids, and insects. However, insects largely dominate, accounting for more than 87% of the species, far in excess of mites (6.4%). Three of the insect orders, namely Coleoptera, Hemiptera and Hymenoptera, overall account for nearly 65 % of the total. The alien fauna seems to be highly diverse with a total of 257 families involved, of which 30 have no native representatives. However, just 11 families contribute more than 30 species, mainly aphids, scales and hymenopteran chalcids. For a number of families, the arrival of alien species has significantly modified the composition of the fauna in Europe. Examples are given. The number of new records of aliens per year has increased exponentially since the 16th century, but a significant acceleration was observed since the second half of the 20th century, with an average of 19.6 alien species newly reported per year in Europe between 2000 and 2008. This acceleration appears to be mainly related to the arrival of phytophagous species, probably with the plant trade, whereas the contribution of detritivores, parasitoids and predators has decreased. Some taxa have not shown any acceleration in the rate of arrivals. Asia has supplied the largest number of alien arthropods occurring in Europe (26.7 %), followed by North America (21.9%) but large differences in the region of origin are apparent between taxa. Once established, most alien species have not spread throughout Europe, at least yet, with 43.6 % of the species only present in one or two countries, and less than 1% present in more than 40 countries. Large differences also exist between European countries in the total number of alien arthropods recorded per country. Italy (700 species) and France (690 species), followed by Great Britain (533 species), host many more species than other countries. The number of alien species per country is significantly correlated with socioeconomic and demographic variables.

Keywords
aliens, arthropods, Europe, globalization, taxonomy, Asia, drivers of biological invasion

Introduction

Expanding world-wide trade, globalisation of economies and climate change are all factors that contribute to an accelerated international movement and establishment of alien organisms, allowing them to overcome geographic barriers (Hulme et al. 2008, Hulme 2009, Walther et al. 2009, Roques 2010). These alien species have already been shown to impose enormous costs on agriculture, forestry as well as to threaten human health and biodiversity (Williamson 1996, Wittenberg and Cock 2001, Pimentel et al. 2002, 2005, Vilá et al. 2009). Although terrestrial arthropods, and particularly insects, represent a large part of the alien species problem, they appear to have received disproportionately less attention compared to plants, vertebrates, and aquatic organisms, especially regarding their possible ecological impact (Kenis et al. 2009). Most of the works concerning alien terrestrial invertebrates have dealt with case studies of pests having a high economic or sanitary impact, such as gypsy moth (*Lymantria dispar* (L.)) in North America (Liebhold et al. 1992), Asian long-horned beetles (*Anoplophora* spp.; Haack et al. 2010), or Asian tiger mosquito (*Aedes albopictus* (Skuse)*;* Eritja et al. 2005). More synthetic studies have been carried out at guild level (e.g., bark beetles; Brockerhoff et al. 2005) or at ecosystem level, especially for forest insects (Liebhold et al. 1995, Mattson et al. 1996, 2007, Niemelä and Mattson 1996, Langor et al. 2009). However, continental inventories of alien arthropod species, or even of alien insects, are still lacking in most regions, although such studies are needed to assess which taxonomic or bio-ecological groups of alien species are better invaders or more harmful to the economy or environment, and which ecosystems or habitats are at greater risk (Mondor et al., 2007).

In Europe, the potential problems caused by alien arthropods have traditionally been considered as less severe than in North America, Australasia or South Africa (Niemelä and Mattson 1996). As a result, unlike other groups of animals and plants, no checklist of alien terrestrial arthropods was available in any of the European countries until the early 2000s. However, in the last 20 years, several exotic pests of economic concern, to name a few, the western corn rootworm (*Diabrotica virgifera virgifera* LeConte), the red palm weevil (*Rhynchophorus ferrugineus* (Olivier)), the harlequin labybeetle (*Harmonia axyridis* (Pallas)), or the chestnut gall maker (*Dryocosmus kuriphilus* (Yasumatsu)), have invaded Europe, inducing more interest in the issue of alien arthropods. The horse-chestnut leaf miner, *Cameraria ohridella* Deschka and Dimić, an alien in Europe originating from the Balkans, has also raised much public concern because of its spectacular damage to urban trees in invaded areas of Central and Western Europe (Valade et al. 2009).

Thus, checklists of alien arthropods began to be compiled from 2002 onwards, successively covering Austria (Essl and Rabitsch 2002), Germany (Geiter et al. 2002), the Netherlands (Reemer 2003), the Czech Republic (Šefrová and Laštůvka 2005), Scandinavia (Nobanis 2005), the United Kingdom (Hill et al. 2005, Smith et al. 2007), Italy (Pellizzari et al. 2005), Serbia and Montenegro (Glavendekić et al. 2005), Switzerland (Kenis 2005), Israel (Roll et al. 2007), Albania, Bulgaria and Macedonia (Tomov et al. 2009), and Hungary (Ripka 2010). However, a major advance in the knowledge of alien arthropod species established in Europe was the European project DAISIE (*Delivering Alien Invasive Species Inventories for Europe*) in 2008. Besides furnishing national and regional lists, this project provided for the first time an overview of the alien fauna of arthropods that has established on the continent. DAISIE identified a total of 1517 alien terrestrial invertebrates, of which 1424 arthropods. However, limited expertise in some taxa during the DAISIE project meant full coverage of all the terrestrial arthropods could not be achieved with the same level of precision. The working group formed on this occasion therefore decided to continue its activity over the next two years, enlarging its taxonomic scope and competencies, in order to provide the most exhaustive list of the alien terrestrial arthropods of Europe as possible, with detailed information about each species.

The update of the DAISIE list revealed in this book accounts for 1590 arthropod species alien to Europe, i.e. 166 more species, including both additions and deletions from the former list, and a much better coverage of taxonomic groups other than insects and spiders (i.e., mites, myriapods and crustaceans). In order to allow a comparison of their invasive patterns, the different taxonomic groups are presented separately in 21 chapters which have the same format. Because of the large number of species in some groups, these have been divided into several distinct chapters; i.e., four chapters for Hemiptera and five chapters for Coleoptera. Each chapter successively analyzes the taxonomy of the alien species component compared to that of the native fauna, the temporal trends of introduction, the biogeographic patterns, including both details of the region of origin and the distribution of the species in Europe, the pathways of introduction, the ecosystems and habitats which are invaded, and the economic and ecological impact of the biological invaders. At the end of each chapter, a table summarizes key information regarding all species in the taxa which are alien *to* Europe; i.e. of ascertained exotic origin or cryptogenic (see Chapter 1 for definitions): family, feeding regime, date and country of first record in Europe, invaded countries, habitats, plant or animal host, and one reference at least (usually that of the first record). In a number of cases, a second table includes a list and similar information for the species considered as alien *in* Europe; i.e. spreading to new countries within Europe, especially for species of Mediterranean origin recorded in more northern areas and species of continental Europe which have colonized islands. We did not provide such tables systematically. Indeed, it was difficult to ascertain for a lot of these species whether they have been introduced in other parts of Europe through direct or indirect human activity - and thus meet our definition of aliens (see Chapter I) - or they are naturally expanding, e.g. with global warming, or even if their native distribution range was incompletely known before their ''discovery' in these new areas.

The geographic range covered in this book is primarily Europe in geographic sense, with the main Mediterranean islands and archipelagos (Balearic Islands, Corsica, Sardinia, Sicily, Malta, Crete, and the Ionian, North Aegean and South Aegean islands) and those of the North Sea (Aland, Svalbard) which are considered separately from the associated continental countries. Ireland was considered as a single biogeographic entity (i.e., Republic of Ireland plus Northern Ireland). Because of their possible importance as a first step for the invasion of continental Europe, the islands of the Altantic Ocean (Madeira, the Canary Islands, The Azores Archipelgao), were also included in the analysis but they may also correspond to a source of aliens of Macaronesian origin colonizing the European continent.

This substantial work allowed us to figure out the relative importance of the different taxa of alien arthropods in a standardized fashion to other groups as well as to compare their respective habitats (Pyšek et al. 2009), and environmental and economic impacts (Vilá et al. 2009). The present chapter presents the most important patterns exhibited by the terrestrial arthropods alien *to* Europe.

2.2 Taxonomy of arthropods alien *to* Europe

Alien terrestrial arthropods represent the second most numerous group of organisms introduced to Europe (Roques et al. 2009). A total of 1364 species originating from other continents have established so far, to which we add 226 more or less cosmopolitan species of uncertain origin (cryptogenic) for a total of 1590 species. Insects largely dominate this list, accounting for more than 87%, far in excess of mites (6.4%) (Figure 2.1). These alien species are dispersed across 33 taxonomic orders, including two orders of crustaceans, 10 of myriapods (three of chilopods, five of diplopods, one of pauropods and one of Symphyla), four of mites, one of arachnids, and 16 of insects. However, the relative importance of each order is highly variable (Figure 2.2). Three of the insect orders, namely Coleoptera, Hemiptera and Hymenoptera, overall account for nearly 65 % of total alien arthropods, representing 25.0%, 20.0% and 18.7%, respectively. The number of alien Hymenoptera established in Europe is thus much higher than previously considered (Daisie 2009). Diptera (6.2 %), Lepidoptera (6.1 %) Thysanoptera (3.3 %) and Psocoptera (3.1 %) have much lower importance as do Prostigmata mites (4.9 %- see Chapter 7.4) and Aranea (3.0 %), the only non-insect orders to exhibit more than 45 alien species. The other orders are anecdotal. It should be noted that some orders show no alien species whereas there are important components of the native fauna such as Trichoptera. More generally, at the order level, the taxonomic composition of the alien fauna significantly differs from that of the native European arthropod fauna. Calculations done on insects have revealed that establishment patterns differ between orders (Roques et al. 2009). Hemiptera are nearly three times better represented in the alien fauna than in the native fauna (20.0% vs. 8.0%). The alien entomofauna also includes proportionally more thrips (3.3 vs 0.6%), psocids (3.1 vs. 0.3%) and cockroaches (1.1 vs. 0.2%) than the native fauna, but much fewer dipterans (6.2 vs. 21%) and hymenopterans (18.7 vs. 25%). Differences are less pronounced for Coleoptera (25.0 vs. 30.0%) and Lepidoptera (6.1 vs. 10%).

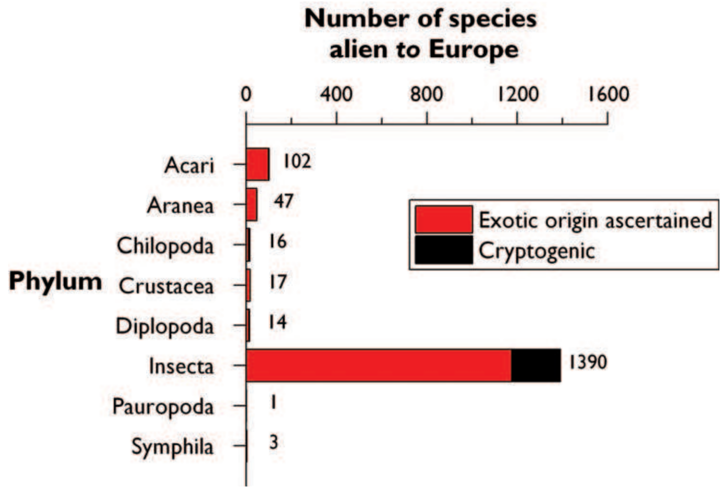

Figure 2.1. Relative importance of the different phyla in the 1590 species of arthropods alien to Europe. Species of ascertained exotic origin and cryptogenic species are presented separately. The number to the right of each bar indicates the total number of alien species observed per phylum.

The alien fauna seems to be highly diverse with a total of 257 families involved. However, only 38 of these families contribute 10 and more alien species, while 11 families more than 30 species (Figure 2.3). These 11 families mostly include hemipterans comprising aphids (Aphididae with the highest number of alien species - 102 spp.) and scales (Diaspididae and Pseudococcidae), as well as hymenopteran chalcids used for biological control such as Aphelinidae (63 spp.) and Encyrtidae (55 spp.), mites (Eriophyidae), and thrips (Thripidae). All of these except snout beetles (Curculionidae) and ants (Formicidae) are tiny arthropods. Noticeably, whilst these families dominate the alien fauna of arthropods, they are less intercepted by the phytosanitary quarantine services at European borders. A comparison done by Roques (2010) between interceptions and establishments of alien species in Europe during the period 1995 – 2005 for the alien insects and mites associated with woody plants in Europe has revealed that the major families of invaders were largely undetected (e.g. aphids, midges, scales, leafhoppers and psyllids). In contrast, the groups which were predominantly intercepted (e.g. long-horned and bark-beetles), actually made little contribution to the established alien entomofauna. Similar results were obtained at country level for Austria, the Czech Republic, and Switzerland (Kenis et al. 2007).

For a number of families, the arrival of alien species has significantly modified the composition of the fauna presently observed in Europe. First, a total of 30 families had no representatives in Europe before the arrival of aliens. These include seven families of myriapods (Henicopiidae - 5 spp., Haplodesmidae, Rhinicricidae, Oryidae, Siphonotidae, Oniscodesmidae, Pseudospirobolellidae, Spirobolellidae, Trigoniulidae - 1 sp. each), four mite families (Listrophoridae - 4 spp., Myocoptidae, Pyroglyphidae and Varroidae - 1 sp. each), and one spider family (Sicariidae - 2 spp.). For insects, no native species existed for three alien families of psocids (Lepidopsocidae - 5 spp., Psyl-

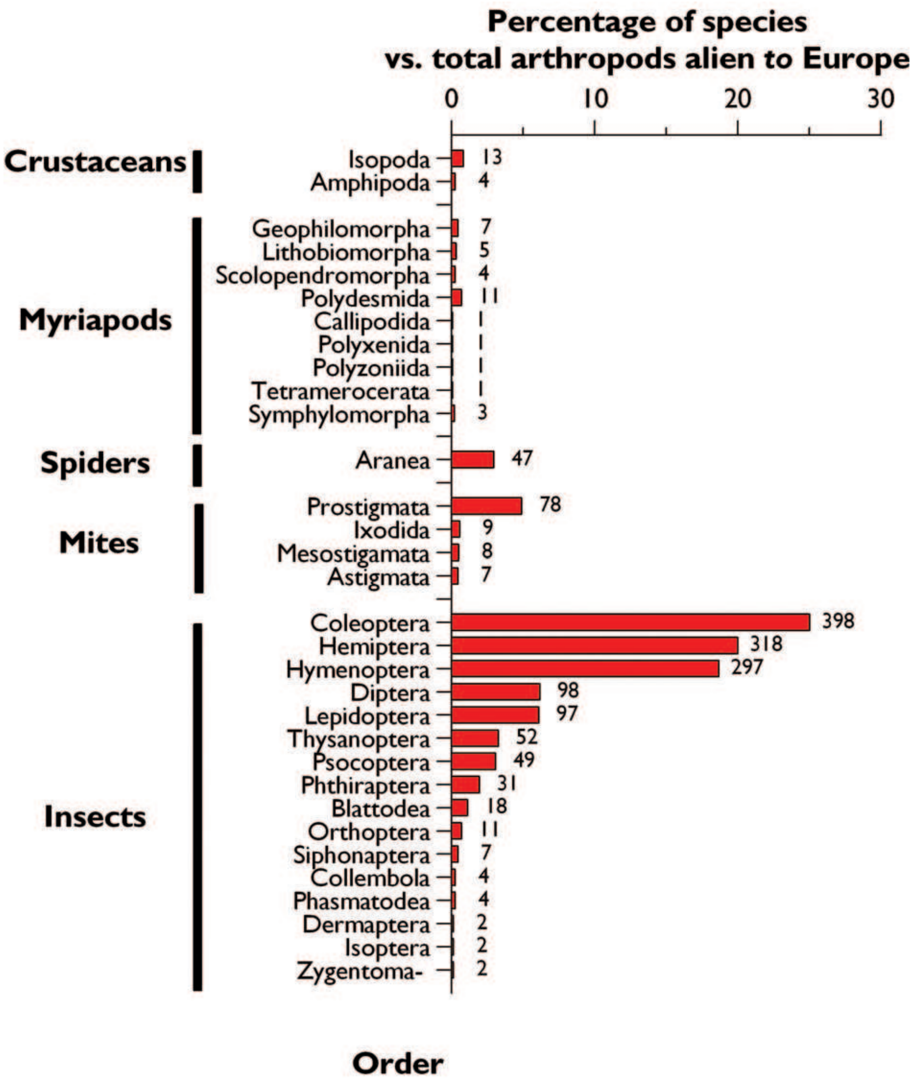

Figure 2.2. Relative importance of the different taxonomic orders in the 1590 species of arthropods alien to Europe. Species of ascertained exotic origin and cryptogenic species are summed. The number to the right of each bar indicates the total number of alien species observed per order.

lopsocidae - 5 spp., and Psoquillidae - 3 spp.), three lice families (Gliricolidae - 2 spp., Gyropidae and Trimenopidae - 1 sp. each), two Blattodea families (Blaberidae - 10 spp., and Blattidae - 6 spp.), two scale families (Phoenicococcidae and Dactylopiidae - 1 sp. each), two beetles families (Ptylodactylidae or little ash beetles - 2 spp. and Acanthonemidae or toe-winged beetles - 1 sp.), one lepidopteran family (Castniidae - 1 sp., the palm moth *Paysandisia archon* (Burmister)), one Phasmatodea family (Phasmatidae - 4 spp.), one family of Hemiptera Auchenorrhyncha (Acanaloniidae - 1 spp.), and one thrips family (Merothripidae - 1 sp.).

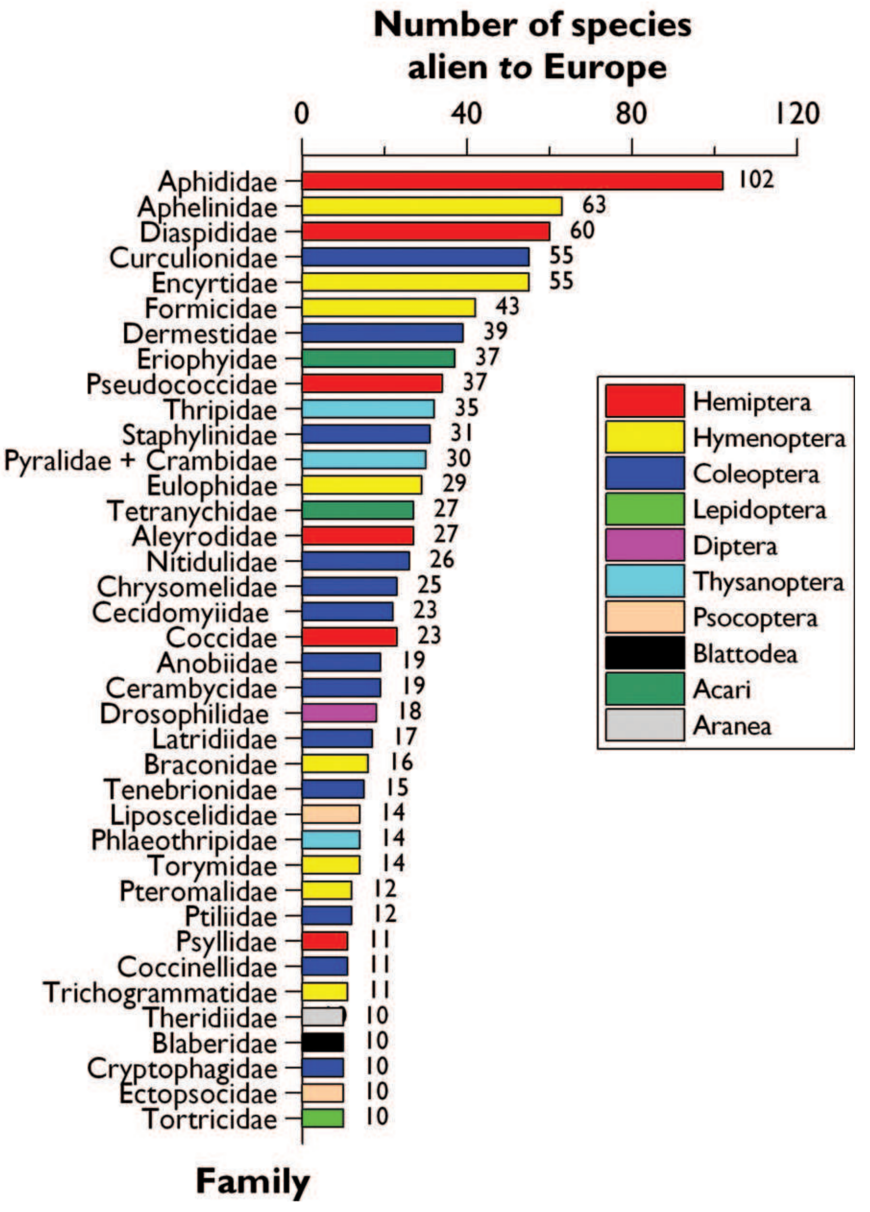

Figure 2.3. Families of arthropods contributing most to the fauna alien *to* Europe. Only the families with numbers of alien species equal to 10 or more are shown. Corresponding taxonomic orders are indicated by different colors. The number to the right of each bar indicates the total number of alien species observed per family.

In some other families, alien species could be over-represented. This is especially true for scales, where aliens now represent nearly half of the total Diaspididae fauna observed in Europe (60 out of 130 species - 44.6 %), a third of the Coccidae fauna (23 out of 70 species - 32.3 %), and a fourth of the Pseudococcidae fauna (37 out of 141 species

- 25.7 %). Similar high proportions of aliens are observed for psocids (Pachytroctidae - 66.7%, Ectopsocidae - 57%, and Liposcelidae - 26.4 %), hemipterans (Aleyrodidae - 39.1 % and Adelgidae - 36.0 %), hymenopterans (Agaonidae - 40.0 %, Apheliniidae 24.2 %, and Siricidae - 23.8%), and saturnid lepidopterans (30.0 %). Even if the relative proportions are lower, the arrival of a large number of alien species has also largely modified the faunal taxonomic structure in dermestid beetles (21.9 % of aliens), tetranychid mites (15.1 %), drosophilid flies (14.8 %), and encyrtid chalcids (7.2 %).

2.3 Temporal trends of arrival in Europe of alien arthropods

Some alien arthropods were introduced to Europe long ago accompanying human movements. For instance, a number of ectoparasites of humans and early-domesticated animals such the head louse (*Pediculus capitis* De Geer), the crab louse (*Phtirus pubis* (L.)), the cat flea (*Ctenocephalides felis felis* (Bouché)), the rat flea (*Xenopsylla cheopis* (Rothschild)) or the human flea (*Pulex irritans* L). are probably allochtonous in Europe, having arrived in ancient times with their hosts (Mey 1988; Beaucournu and Launay, 1990). Thus, *Pulex irritans* was shown to have been present in Europe since the Bronze Age at least, having been found in remains of lake dwellings in the French Jura, dating back to 3100 B.C. (Yvinec et al. 2000). Fragments of insects related to stored products were also found in Roman and Viking graves (e.g., *Sitophilus granarius*; Levinson and Levinson 1994). However, unlike plants and other animal groups, a clear identification of the *archaeozoans** has appeared difficult for arthropods. Therefore, we only qualified as aliens the *neozoan** species, i.e. those having likely been introduced after 1500.

The introduction of alien arthropods is usually accidental, the release of biological control agents remaining limited, as well as the escape of arthropod 'pets' from captivity (see Chapter 3). Thus, the introduction phase is rarely observed and pathways of introduction are poorly known. Consequently, an alien arthropod is usually discovered when it is already established, spreading and causing damage. The precise date of arrival in Europe is not known for most species. Even conspicuous species, such as the Asian long-horned beetle, *Anoplophora glabripennis* (Motschulsky), have been reported with a delay of at least 3–5 years since establishment (Herard et al. 2006). However, taking into account these caveats, the date of first record in Europe- the single temporal datapoint usually obtainable- may be used as a proxy for the date of first arrival.

The date of first record in Europe, relying on published papers, could be obtained for 1421 of the 1590 alien species (89.4%). The number of new records per year appears to have increased exponentially since the 16th century, but a significant acceleration was observed during the second half of the 20th century (Figure 2.4a). As a probable result of globalization, this trend is still increasing with an average of 19.6 alien species newly reported per year in Europe between 2000 and 2008; i.e., a value nearly double the 10.9 species that were observed per year during the period 1950- 1974.

In order to understand better this process, we decompose the values according to the feeding regime of the alien species (Figure 2.4b). Fluctuations in the number of

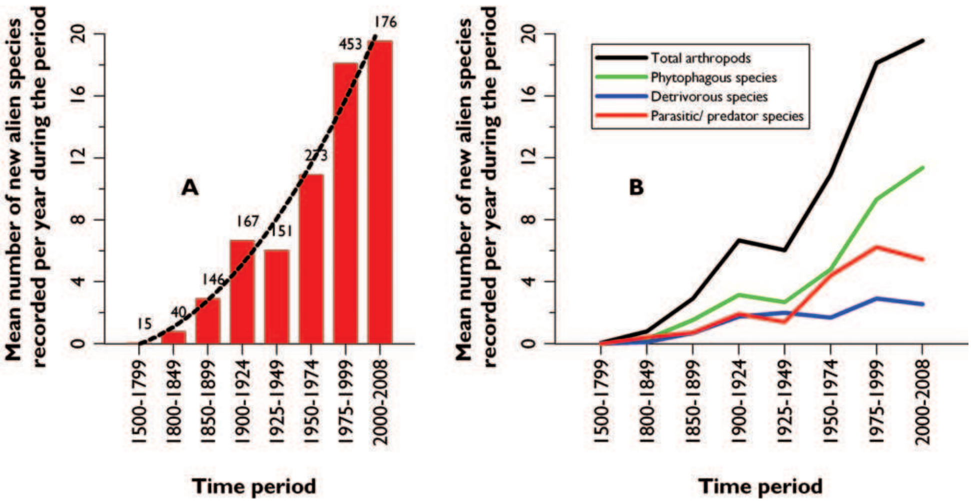

Figure 2.4. Temporal changes in the mean number of new records per year of arthropod species alien *to* Europe from 1500 to 2008. **A** Total arthropods (Best fit: $y= -0.411- 0.407x + 0.304 x^2$; $r^2 = 0.965$) **B** Detail per feeding regime.

total arthropods newly arriving per year in Europe appear to be strongly dependent on the increasing arrival of phytophagous species, especially during the last ten years. In contrast, the number of detritivores and parasitoids/ predators has appeared to decrease during this last decade, and contributed much less to the overall increase, whereas these three feeding guilds had contributed more or less equally during the first half of the 20th century. After the period 1950- 2000 when alien parasitoids and predators markedly increased probably in relation with the wave of releases of biological control agents, the explosion of ornamental trade since the 1990s is likely to have triggered the arrival of alien phytophagous arthropods, as has been shown for insects related to woody plants (Roques 2010). Specific analyses per taxa have confirmed these tendencies. Whereas the arrival of mites (see Figure 7.4.2), scales (see Figure 9.3.2.), flies (see Figure 10.2) or lepidopterans (see Figure 11.2), which are mainly phytophagous groups, has revealed a similar acceleration in the number of newly recorded aliens during the last period, no such trend has been observed for the parasitic lice and fleas (see Chapter 13.4), nor for the detritivorous Blattodea (see Chapter 13.3).

2.4 Biogeographic patterns of arthropod species alien *to* Europe

Origin of the species alien to Europe

A precise region of origin was ascertained for 1271 species (79.9%) of the 1590 alien arthropod species, while 93 species were only known to be native to tropical or subtropical regions. The remaining 226 cryptogenic invertebrates are mostly cosmopolitan species for which there is no agreement regarding their area of origin. This is particularly true for stored products pests and for some ectoparasites on cattle and pets that occur on other continents. A few other cryptogenic species have appeared in Europe without having been detected elsewhere. However, data on their phylogeography, population ecology, parasitoids and dispersal biology strongly suggest that they originate from another continent. The horse-chestnut leaf miner, *Cameraria ohridella*, is illustrative of the difficulty in identifying the native range of such species. Whereas this leaf miner was previously considered as an extra- European alien, recent genetic studies indicate that it originates from the southern Balkans (Valade et al. 2009).

Asia has supplied the major part of the alien arthropods occurring in Europe (26.7 %) followed by North America (21.9%) (Figure 2.5). Analysing specifically insect data per time unit has revealed that the relative contribution of Asia and North America was stable over time (Roques et al. 2009). During the periods 1950–1989 and 1990–2007, 29% and 21% of the established insects were of Asian and North American origin respectively. The contribution of tropical and subtropical areas is surprisingly important. The overall contribution of species from Australasia, Africa, Central and South America in combination with species of undefined tropical areas represents 37% of all alien insects in Europe. While we agree that insect species coming from these areas are not just native to tropical ecosystems, this proportion is nevertheless outstanding.

Unlike the temporal trends, the regions of origin do not differ significantly between feeding regimes. Asia is the main region of origin for alien phytophages, parasitoids/ predators and detrivorous species although a bit less important for the latter group (Figure 2.5).

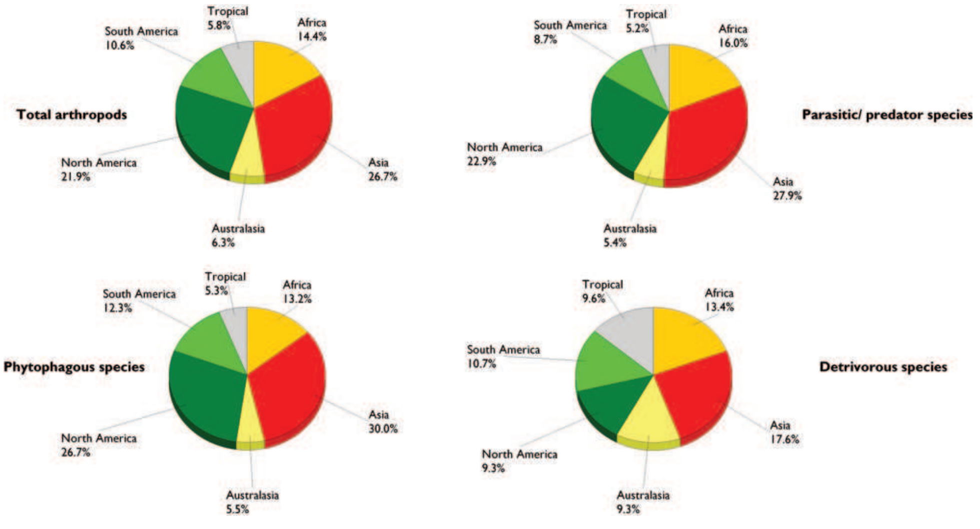

Figure 2.5. Region of origin of the 1590 arthropod species alien *to* Europe. Total arthropods and breakdown per feeding regime are presented. Percentages of the total per category are shown under each region.

However, a comparison of the native range of species from the different orders revealed significant differences (χ_2= 388.26; P=0.0000). Most mites (51.5% - see Figure 7.4.3), hymenopterans (32.3 % - see Figure 12.3), and dipterans (30.6 %- see Figure 10.3) have arrived from North America whilst 37.2 % of lepidopterans (see Figure 11.3) and 31.5 % of hemipterans have originated from Asia. Coleoptera have come from various regions, including a significant component from Australasia (9.5%) mostly linked to the introduction of *Eucalyptus* and *Acacia* spp. in the Mediterranean regions of Europe. Coleoptera also represent a large proportion of the cosmopolitan stored product pests that are predominantly of tropical or subtropical origin.

Patterns of spread

Once established, most alien species have not spread throughout Europe, at least yet. We used the presence in a country as a proxy of the invaded range because it appeared impossible to get sufficient data for a quantitative assessment of this invaded range area for most alien species. A total of 694 species (i.e., 43.6 %) have not invaded more than one country/ island additional to the one where they arrived, and 63.6 % are present only in five European countries (Figure 2.6). Less than 1% (12 out of 1590) of the alien arthropods are present in more than 40 countries; among these are the melon and cotton aphid, *Aphis gossypii* Glover, and several beetles associated with stored products especially seed bruchids (e.g.,. *Callosobruchus chinensis* (L)). Detritivorous species appeared to have dispersed significantly more (8.5±0.5 countries) than phytophagous species (7.1±0.3) and parasitoids/ predators (5.5±0.3) (Krsukall-Wallis test. $F_{2,1598}$= 10.97; P=0.0000).

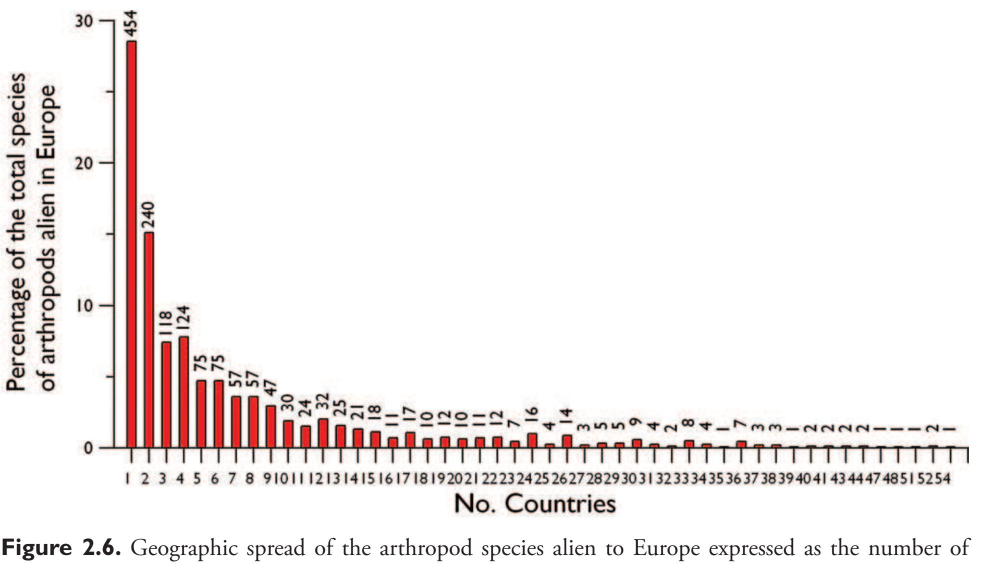

Figure 2.6. Geographic spread of the arthropod species alien to Europe expressed as the number of countries colonized by these species and their frequency.

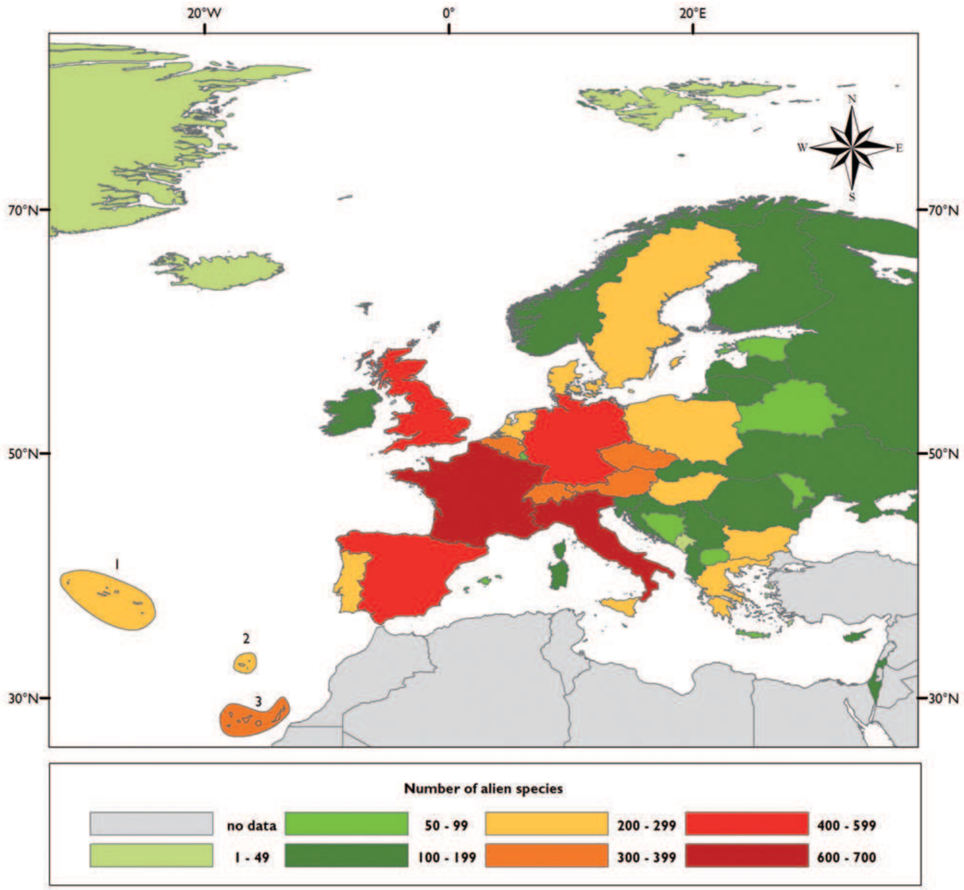

Figure 2.7. Comparative colonization of continental European countries and islands by dipteran species alien *to* Europe. Archipelagos: **1** Azores **2** Madeira **3** Canary islands.

Large differences also exist between European countries in the total number of alien arthropods recorded per country (Figure 2.7 and 2.8). Italy (700 species) and France (690 species), followed by Great Britain (533 species), host many more species than other countries. The same ranking is obtained when the number of alien species per km^2 is considered. Differences in sampling effort may have affected the analyses. However, the number of alien insects is significantly and positively correlated with country surface area (r= 0.3621; P= 0.0384). More westerly countries and islands appear in general relatively more colonized. The number of alien species significantly decreases with the longitude of the countries' centroids (r= -0.6988; P= 0.0038) whereas latitude does not seem to have a significant influence (r=-0.378; P= 0.168). Islands also host proportionally more alien species than continental countries relative to their size (Kruskall-Wallis test on the number of alien species per km^2; $F_{1,53}$ = 6.20; P=0.0160) but this is independent of the coast length (r= 0.174; P= 0.384). In continental countries, bordering the sea does not influence the number of alien insect spe-

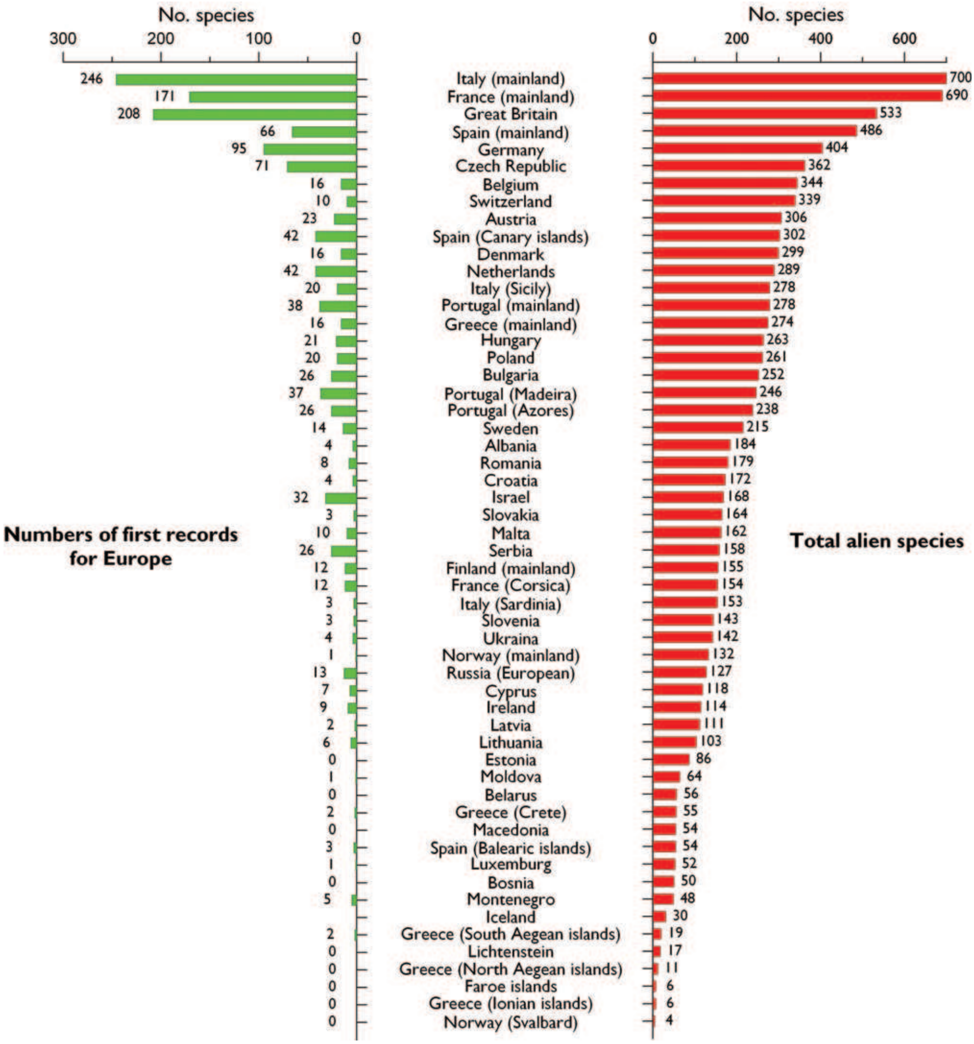

Figure 2.8. Comparison between the number of first records for Europe observed for the alien species in a country (left) and the total number of alien species now present in the country (right).

cies (P=0.6404). In addition, the country or island where a species was first recorded in Europe has been identified for 1399 species out of the 1590 alien arthropods (Figure 2.8). The same country ranking was obtained as for the total number of arthropods present per country. Indeed, there is significant correlation (r= 0.8745; P=0.0000) between the two values.

However, much stronger correlations exist between the number of alien arthropods in a country and the total volume of merchandise imports of the country (r= 0.875; P=0.0000), the density of the road network (r= 7578; P= 0.0001), and the size of the human population (r= 0.5918; P= 0.0047). These results confirm the decisive importance of socioeconomic and demographic drivers in arthropod invasion.

References

Brockerhoff EG, Bain J, Kimberley M, Knížek M (2006) Interception frequency of exotic bark and ambrosia beetles (Coleoptera: Scolytinae) and relationship with establishment in New Zealand and worldwide. *Canadian Journal of Forest Research* 36: 289–298.

DAISIE (Ed) *The Handbook of Alien Species in Europe*. Heidelberg, Germany: Springer. 399 pp.

Eritja R, Escosa R, Lucientes J, Marquès E, Roiz D, Ruiz S (2005) Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. *Biological Invasions* 7: 87–97.

Essl F, Rabitsch W (Eds) (2002) Neobiota in Österreich. Umweltbundesamt, Wien. 432 pp.

Geiter O, Homma S, Kinzelbach R (2002) Bestandsaufnahme und Bewertung von Neozoen in Deutschland. Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potentiellen Effekten gentechnisch veränderter Organismen. Berlin: Umweltbundesamt.

Glavendekić M, Mihajlović L, Petanović R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro. In: *Plant protection and plant health in Europe: introduction and spread of invasive species*. BCPC Conference, Humbolt University, Germany, June 2005, 229–230.

Hérard F, Ciampitti M, Maspero M, Krehan H, Benker U, Boegel C, Schrage R, Bouhot-Delduc L, Bialooki P (2006) *Anoplophora* species in Europe: infestations and management processes. *Bulletin OEPP/EPPO Bulletin* 36: 470–474.

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46: 10–18.

Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I, Minchin D, Nentwig W, Olenin S, Panov V, Pergl J, Pyšek P, Roques A, Sol D, Solarz W, Vilà M (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. *Journal of Applied Ecology* 45: 403–414.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Délemont: CABI Bioscience Switzerland, 131–212.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Péré C, Cock MJW, Settele J, Augustin S, Lopez-Vaamonde C (2009) Ecological effects of invasive alien insects. *Biol Invasions* 11: 21–45.

Kenis M, Rabitsch W, Auger-Rozenberg MA, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Langor DW, DeHaas L, Foottit RG (2009) Diversity of non-native terrestrial arthropods on woody plants in Canada. *Biological Invasions* 11: 5–19.

Liebhold AM, Halverson JA, Elmes GA (1992) Gypsy moth invasion in North America: a quantitative analysis. *Journal of Biogeography* 19: 513–520.

Liebhold AM, MacDonald WL, Bergdahl D, Mastro VC (1995) Invasion by exotic forest pests: a threat to forest ecosystems. *Forest Science Monographs* 30: 1–49

Mattson WJ, Niemelä P, Millers I, Inguanzo Y (1994) *Immigrant phytophagous insects on woody plants in the United States and Canada: an annotated list*. General Technical Report NC-169. St. Paul, Minnesota, USA: USDA Forest Service, North Central Forest Experiment Station.

Mattson WJ, Vanhanen H, Veteli T, Sivonen S, Niemelä P (2007) Few immigrant phytophagous insects on woody plants in Europe: legacy of the European crucible? *Biological Invasions* 9: 957–974 .

Mondor EB, Tremblay MN, Messing RH (2007). Morphological and ecological traits promoting aphid colonization of the Hawaiian Islands. *Biological Invasions* 9: 87–100.

Niemelä P, Mattson WJ (1996) Invasion of North American forests by European phytophagous insects: legacy of the European crucible? *BioScience* 46: 741–753.

Nobanis (2005) *The North European and Baltic Network on Invasive Alien Specie*s. www.nobanis.com.

Pelizzari G, Dalla Monta L, Vacante V (2005) List of alien insect and mite pests introduced to Italy in sixty years (1945 – 2004). In: *Plant protection and plant health in Europe: introduction and spread of invasive species*. BCPC Conference, Humbolt University, Germany, June 2005, 275.

Pimentel D, Lach L, Zuniga R, Morrison D (2002) Environmental and economic costs associated with non-indigenous species in the United States. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 285–306.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–88.

Pyšek P, Bacher S, Chytry M, Jarošik V, Wild J, Celesti-Grapow L, Gasso N, Kenis M, Lambdon PW, Nentwig W, Pergl J, Roques A, Sol D, Solarz W, Vila M, Hulme PE (2009) Contrasting patterns in the invasions of European terrestrial and freshwater habitats by alien plants, insects and vertebrates. *Global Ecology and Biogeography* 19: 317–331.

Reemer M (2003) Invasieve Arthropoda in Nederland: Een eerste inventarisatie. Leiden: Stichting European Invertebrate Survey. 63 pp.

Ripka G (2010) [An overview of the alien arthropod pest species in Hungary (I.)] (in Hungarian). *Növényvédelem* 2.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Roques A (2010) Alien forest insects in a warmer world and a globalized economy: Impacts of changes in trade, tourism and climate on forest biosecurity. *New Zealand Journal of Forestry*, suppl 40: 77–94.

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: DAISIE (Ed) *The Handbook of Alien Species in Europe*. Heidelberg, Germany: Springer, 63–79.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP, Ostojá-Starzewski JC, Collins DW (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology* 9: 307–326.

Tomov R, Trencheva K, Trenchev G, Cota E, Ramadhi A, Ivanov B, Naceski S, Papazova-Anakieva I, Kenis M (2009) *Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia*. Sofia-Moscow: Pensoft, publishers, 112 pp.

Valade R, Kenis M, Hernandez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive Horse-Chestnut leaf miner Cameraria ohridella (Lep. Gracillariidae). *Molecular Ecology* 18 : 3458–3470.

Vilá M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE and Daisie Partners (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European cross-taxa assessment. *Frontiers in Ecology and the Environment* 8: 135–144.

Walther GR, Roques A, Hulme PE, Sykes MT, Pyšek P, Kühn I, Zobel M, and members of the ALARM Climate Change – Biological Invasions Working Group (2009) Alien species in a warmer world: risks and opportunities. *Trends in Ecology and Evolution* 24: 686–692.

Williamson M (1996) Biological Invasions. London: Chapman and Hall. 244 pp.

Wittenberg R, Cock MJW (Eds) (2001) *Invasive alien species: a toolkit of best prevention and management practices.* Wallingford, UK: CABI Publishing. 228 pp.

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Pathways and vectors of alien arthropods in Europe Chapter 3

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Abstract

This chapter reviews the pathways and vectors of the terrestrial alien arthropod species in Europe according to the DAISIE-database. The majority of species (1341 spp., 86%) were introduced unintentionally, whereas 218 species (14%) were introduced intentionally, almost all of these for biological control purposes. The horticultural/ornamental-pathway is by far the most important (468 spp., 29%), followed by unintentional escapees (e.g., from greenhouses, 204 spp., 13%), stored product pests (201 spp., 12%), stowaways (95 spp., 6%), forest and crop pests (90 spp. and 70 spp., 6% and 4%). For 431 species (27%), the pathway is unknown. The unaided pathway, describing leading-edge dispersal of an alien species to a new region from a donor region where it is also alien, is expected to be common for arthropods in continental Europe, although not precisely documented in the data. Selected examples are given for each pathway. The spatiotemporal signal in the relevance of pathways and vectors and implications for alien species management and policy options are also discussed. Identifying and tackling pathways is considered an important component of any strategy to reduce propagule pressure of the often small and unintentionally translocated, mega-diverse arthropods. This requires coordination and clear responsibilities for all sectors involved in policy development and for all associated stake-holders.

Keywords

alien species, non-native species, pathways, vectors, Europe

3.1 Introduction

To become an alien species, boundaries of natural distribution ranges must be overcome with the help of man-made structures, goods and services. These activities and purposes are the pathways of invasions. A plethora of vectors, which are the agents of these translocations, is available to break new grounds and reach new areas. Interestingly, there is no common understanding in this separation in the biological invasion literature (e.g. Ruiz and Carlton 2003, Carlton and Ruiz 2005, Nentwig 2007, Hulme et al. 2008). In this overview, however, pathways are understood as the routes (including motivations to use them) and vectors as the physical objects (ships, plants etc) that carry species along. Several attempts to further classify pathways and vectors are available (e.g. Carlton and Ruiz 2005), but here I follow Hulme et al. (2008), who identified six principal pathways for biological invasions (Table 3.1). Only one of these is founded by intentional motivations, that is the deliberate release of organisms, with biological control as the most important example. The others are utilised unintentionally, accidentally and may come from any direction. These are escapes from contained environments and captivity; contaminants of commodities; stowaways, transported as hitch-hikers with vehicles and cargo; corridors, where transport infrastructure enables the spread of a species; and the unaided pathway, where an alien species conquers a nearby region under its own dispersal capacity. Evidently, these different pathways have major implications for risk assessment, regulations, management and control (Hulme et al. 2008, Hulme 2009).

Human-mediated translocations differ from natural dispersal by orders of magnitude both quantitatively and qualitatively as can be seen by island colonization rates (e.g. Gillespie and Roderick 2002, Gaston et al. 2003) and genetic consequences (e.g. Wilson et al. 2009). Also, the origin of the source differs as natural colonization usually happens from adjacent populations, whereas translocated individuals may come from all over the world.

In the DAISIE-database, three levels of pathways, are distinguished. At the first level, intentional and unintentional ambitions are classified. At the second level, pathways are identified, except that the contaminant, stowaway and corridor pathways are summarized as "transport". At the third level, these are further specified into broad categories (e.g. biological control, crops, horticultural/ornamental, forestry, stored products). In addition, at the second and third level, the category "unknown" is also used and assigned to 392 and 431 species, respectively (25–27%). This is a similar contingent as for the exotic insects in Japan (24%, Kiritani and Yamamura 2003). Introductions of species are not necessarily restricted to one pathway; many species can be considered "polyvectic" (Carlton and Ruiz 2005), transported by more than one pathway or multiple vectors. Accordingly, some species in the DAISIE-database were assigned to more than one pathway/vector. Furthermore, it has to be said very clearly that many assignments were only "best guess" or "most likely" assessments, deduced from the preferred habitats, food

Table 3.1. Pathway terminology and examples of vectors of terrestrial alien arthropod species in Europe.

Pathway	Motivation	Vectors	Examples
Release	Intentional	None	Biological control
Escape	Unintentional	None	Greenhouses
Contaminant	Unintentional	Food sources, ornamentals, vegetables, fruits, wood, animals, ...	Stored product pests, Wood-borers, Leaf-miners, Gall-producers, Endoparasites
Stowaway	Unintentional	Any cargo	Ants, Cockroaches
Corridor	Unintentional	Ships, cars	*Cameraria ohridella*
Unaided	Unintentional	None	Secondary spread from point of entry

plants or ecology, because the intimate pathway/vector of many arthropod species often remains ambiguous.

In this chapter, pathways and vectors of the terrestrial alien arthropods in Europe are reviewed, with the few alien aquatic insects included, but excluding other freshwater alien arthropods such as crayfish species. There are a multitude of further pathways relevant for the marine and freshwater environments (e.g. ballast water, hull-fouling) and for other organisms such as vascular plants and vertebrates (e.g. seed contamination, hunting, pets) (e.g. García-Berthou et al. 2005, Galil et al. 2009, Genovesi et al. 2009).

3.2. Intentional release

With few exceptions, terrestrial arthropods are not intentionally imported. Such exceptions are grasshoppers and crickets as pet food and – more significantly – domesticated honeybees (*Apis mellifera*) of different provenances (subspecies), which are used for breeding, with the aim of producing higher honey yields (Jensen et al. 2005, Moritz et al. 2005). The same is true for the bumblebee subspecies used for pollination in greenhouses (e.g., *Bombus terrestris dalmatinus* in the UK, Ings et al. 2006).

At the end of the 19th century, two saturniid moths, *Samia cynthia* and *Antheraea yamamai*, were introduced from Asia for silk production, but yields was not profitable enough for this to be continued. Both species persist locally in the wild in Europe with most populations being initiated by escapes or releases by amateur lepidoptera-breeders.

Intentional releases for human food consumption are more prevalent for organisms such as molluscs, fish and aquatic Crustacea (oysters, snails, crayfish, crabs), which are not included in this book. Also, there are no "game insects", and only a few pets. Further, there are no introductions of arthropods for aesthetic or conservation purposes (but see further below), a major pathway for other animal groups around the globe (e.g. Nentwig 2007). In the DAISIE-database, 218 species (14%) were introduced intentionally, almost all of these for biological control purposes (Table 3.2).

Table. 3.2. Pathways of the alien arthropod species in Europe, according to the DAISIE-database. Due to double entries the sum differs.

Pathway	Number of species (%)	
Intentional	218 (14%)	
Released		175 (11%)
Unintentional	1341 (86%)	
Animal husbandry		42 (2.6%)
Greenhouse escapees		204 (13%)
Crops		70 (4.3%)
Forestry		90 (5.6%)
Horticultural/Ornamental		468 (29%)
Leisure		13 (0.8%)
Stored products		201 (12%)
Stowaways		95 (5.9%)
Unknown		431 (27%)

3.2.1. Biological control: Ecology vs Economy

The most important pathway for deliberate release of terrestrial alien arthropods is biological control (BC). There has been some controversy about the pros and cons of this technique to control pest organisms (e.g. Howarth 1991, van Lenteren et al. 2006, Babendreier 2007, Murphy and Evans 2009). Whereas non-target effects are considered problematic by conservationists, these are often considered acceptable from an economic point of view. Hence, the underlying basic assumptions and intentions for this controversy are entirely different and comparisons awkward.

BC makes use of the "enemy-release" of introduced organisms, which are disburdened from their natural predators or parasites and boom in the new range. Subsequently, mass-reared releases of those enemies from the original area are conducted, aiming at permanent establishment and control of the pest organisms below damaging thresholds. Not particularly from a "pathway point-of-view", but from a general assessment of non-target effects, it is useful to distinguish between this classical BC and augmentative BC, where control is achieved by periodic releases without permanent establishment intended. Similarly, flightless strains of *H. axyridis* were released in the Czech Republic in 2003 to control for aphids with the goal of no further unaided spread (Brown et al. 2008).

In Europe, there are both success-stories and failures to report from intentional releases, with the former prevailing (e.g. *Encarsia formosa* used against whiteflies in greenhouses; *Trichogramma brassicae*, an "alien in Europe" used against European corn borer *Ostrinia nubilalis*; *Aphelinus mali* from North America used against the Woolly apple aphid *Eriosoma lanigerum*).

Occasionally, released enemies are aliens from other regions than their targets. In Europe, for example, the San Jose scale *Diaspidiotus perniciosus*, described from California, but introduced with infested trees or fruits from Asia, is considered a pest in commercial fruit orchards causing economic losses due to reduced yields. Negative effects are mitigated by application of Neem and other oils, but also by release of the North American parasitoid wasp *Encarsia perniciosi*, which is used for control in North America.

In general, however, the application of BC has been of subordinate relevance in Europe, compared to other regions of the world. The same is true for the application of other technologies where arthropods are released (SIT – Sterile Insect Technique; RIDL – Release of Insects carrying a Dominant Lethal), which may be applied to control alien agricultural pests and mosquitos (Thomas et al. 2000, Alphey et al. 2009).

Ex-situ conservation or reintroduction programmes in insects are still rare, but they do occur for some native species in Europe (butterflies in the UK: Oates and Warren 1990; *Erebia epiphron* in the Czech Republic: Schmitt et al. 2005; *Gryllus campestris* in the UK and Germany: Witzenberger and Hochkirch 2008). Recently, controversial discussions on assisted colonization have emerged in the context of protecting species from climate change by translocating and releasing them beyond their current range limits (e.g. Hoegh-Guldberg et al. 2008, Ricciardi and Simberloff 2009).

3.3. Unintentional release

The unintentional translocation of species is the most common pathway for alien arthropod species invasions into Europe (86% of the species, Table 3.2).

3.3.1. Escapes: Out of the Green

Arthropods are infrequently domesticated, reared and used as pets, although examples of tropical species do exist (e.g. tarantulas, walking sticks and leaves, leaf-cutting ants, millipedes). Establishment in the wild in Europe is highly unlikely for such species, even under severe climate change scenarios. However, escapes from captivity do regularly occur, although they are rarely noticed and published. Insects reared as living food for vertebrate pets (e.g. crickets, grasshoppers, mealworms) seem to be of limited significance, whereas pests and insects used for biological control in semi-contained environments, particularly greenhouses, are of much greater importance. Greenhouses are not escape-proof facilities for insects as confirmed by surveys in the areas surrounding such buildings (e.g. Vierbergen 2001, Aukema and Loomans 2005). Well-known examples include the Western Flower Thrips *Frankliniella occidentalis*, the Cotton Aphid *Aphis gossypii*, and the Cotton Whitefly *Bemisia tabaci*, all of which reproduce in the field in southern Europe but are restricted to greenhouses in western, central, or northern Europe. Serving as stepping stones, it is expected that some future invaders in Europe will be recruited out of this pool of species, particularly if climate warms as predicted. In the DAISIE-database, more than 200 arthropod species are listed as living in greenhouses.

One of the most famous stories of a greenhouse escapee is the Multicoloured Asian lady beetle or Harlequin ladybird *Harmonia axyridis*, termed the "most-invasive ladybird on Earth" (Roy et al. 2006). This large coccinellid beetle, native to East-Asia, was introduced to North America and Europe for aphid control in greenhouses, but escaped into the wild. It is a highly competitive intra-guild predator reducing and displacing native coccinellid species and other members of the aphid-feeding guild (Roy and Wajnberg 2008). Its subsequent unaided spread across much over Europe within just a few years (Brown et al. 2008) highlights the capacity of invasive alien species to successfully conquer naïve environments.

3.3.2. Contaminant: Going for a ride?

The contaminant pathway describes the unintentional transport of species within or on a specific commodity, contrary to stowaways, which are accidentally associated with any commodity. Stored product pests, for example, are translocated with the movements of the products and many species have subsequently achieved a cosmopolitan distribution. In Europe, 201 alien insect species (12%) were introduced as stored product pests, feeding on a variety of food sources (e.g. cereals, rice, seeds, nuts, fruits) with considerable economic damage, including species which are likely to have been introduced by human activities in neolithic or pre-Christian centuries, e.g. *Sitophilus granarius* and *Oryzaephilus surinamensis* (Levinson and Levinson 1994). In Europe and temperate regions in general, care of stored products achieves higher protection levels than in subtropical and tropical areas, where up to 10% of weight loss may occur, representing loss of nutritional quality, with associated impacts on human welfare (Rees 2004).

Other pest species are strictly associated with the exchange or trade of their host plants (e.g. ampelophagous species feeding exclusively on grapevines - *Viteus vitifoliae*, *Scaphoideus titanus*; species feeding exclusively on palms - *Rhynchophorus ferrugineus*, *Diocalandra frumentii*; monophagous leaf-miners and gall-producers - *Parectopa robiniella*, *Phyllonorycter robiniella*, *Dryocosmus kuriphilus*) and therefore directly related to these vectors.

Other examples include phytophagous species translocated with ornamentals or horticultural host plants (e.g. scales and aphids) and xylophagous bark- and wood-infesting insects, above all beetle larvae, feeding in living trees. One of the best known examples is the Citrus longhorned beetle *Anoplophora chinensis*, which has repeatedly been reported infesting Bonsais imported from China. Larvae of *A. chinensis* and more often of the Asian longhorned beetle *Anoplophora glabripennis* were also intercepted with wood packaging material (see Haack et al. 2010 for a review). Recognizing the relevance of this vector enforced adoption of the International Standard for Phytosanitary Measures No. 15, which sets standards for thermal and chemical treatment of wood packaging material used for international trade. Although now found in lower numbers, living beetles are still being intercepted, indicating some gaps in this procedure.

Roques (2010) assembled examples of the possible introduction of alien insects during major international events such as the 2004 Olympic Games in Athens, where imported palm trees were widely planted and coincided with the first arrival of the red palm weevil *Rhynchophorus ferrugineus*.

The most striking example of contamination is associated with the introduction of the Potato (Colorado) beetle, *Leptinotarsa decemlineata*, to Europe. Spanish conquistadors in the 16th century brought the potato plant from South America to Europe, although it was not appraised as a human food source until the mid-17th century. After a severe decline of potato cultivation in Ireland in 1845–1857, caused by the introduced potato blight fungi *Phytophthora infestans*, emigrants brought the plant to North America, where the beetle exploited the new host plant. Between 1876 and 1922, the beetle was subsequently introduced into Europe on several occasions, not being able to establish in European potato fields until 1922, when it succeeded in France. The beetle has since spread east throughout Europe and Asia, reaching China in the 1980s (Alyokhin 2009). It should also be noted that the Colorado beetle was involved in propaganda to defame Great Britain and the United States of America during World War II and the Cold War.

Kenis et al. (2007) found that the majority of alien insects for Austria and Switzerland were contaminants and stowaways, with, in decreasing order, host plants (40% of which on ornamentals and 20% on vegetables and fruits), stored products and wood material as the main sources. Similar results were obtained with interceptions documented by EPPO between 1995 and 2004 (Roques and Auger-Rozenberg 2006). Altogether, introductions of arthropods with ornamental and horticultural plants and plant material, cut flowers, vegetables, and fruits, clearly preponderate in the DAISIE-data (29%, Table 3. 2). It is self-evident that there is a taxonomic bias with the type of commodity. For example, plant-feeding species (e.g. aphids, scales) are closely associated with ornamental plants, whereas wood-boring species (e.g. scolytids, cerambycids) are linked to living and dead wood imports. A rather uncommon invasion history pertains to the inadvertent introduction of the nearctic waterboatman *Trichocorixa verticalis* into Portugal and Spain. It is likely to have happened with the import and release of Eastern Mosquitofish *Gambusia holbrooki* for mosquito control (Sala and Boix 2005).

Living organisms as well as commodities can be contaminated. For example, many haematophagous alien arthropod species (e.g. Culicidae, Siphonaptera, Phthiraptera, Ixodidae) host parasites and pathogens and serve as reservoir, carriers or biovectors of human and animal infectious diseases. Moreover, phytophagous alien arthropod species (e.g. Hemiptera) may transmit plant pathogens (e.g. phytoplasmas, viruses).

Several examples are associated with beekeeping. Both endoparasites (the tracheal mite *Acarapis woodi*) and ectoparasites (the notorious *Varroa*-mite *Varroa destructor*), inquiline scavengers (the Small Hive Beetle *Aethina tumida*, captured only once in Europe and eradicated in quarantine in Portugal), and bacterial and fungal diseases (chalkbrood, foulbrood, nosemosis) are exchanged throughout the globe through honeybee imports (e.g. Sammataro et al. 2000, Coffey 2007).

The ultimate agent of Colony Collapse Disorder (CCD) known from North America, Europe and Asia is still under debate (e.g. Ratnieks and Carreck 2010) and it may well be a multi-triggered phenomenon, which causes the complete disappearance of adult worker bees of a colony. Beside environmental causes (e.g. pesticides), several diseases and pathogens are suspected to contribute or elicit CCD, e.g. *Nosema ceranae*, a microsporidian native to Asia and suspected to have host-switched to the European honeybee (Klee et al. 2007, Higes et al. 2009).

3.3.3. Stowaways: Where do you want to go today?

Stowaways are unintentionally introduced organisms that are related to transport infrastructure and vehicles, but independent of the type of commodity. Translocation with ballast water or soil movement are typical examples. In terrestrial environments, any cargo transported by air, water or land has the potential to move species beyond their natural range and habitat boundaries. Several cockroach species, e.g. *Blatta orientalis* and *Periplaneta americana*, are typical stowaways, having been translocated worldwide. Kiritani and Yamamura (2003) argued that passenger hand luggage arriving in airplanes to Japan may contain one consignment infested by fruit flies each day. Roughly two thirds of the intercepted pest species at US ports of entry between 1984 and 2000 were associated with baggage, and a further 30% with cargo (McCullough et al. 2006). However, to a certain extent, the separation between the contaminant and the stowaway pathway is ambiguous or not mutually exclusive.

Roques et al. (2009) cites the Asian tiger mosquito *Aedes albopictus* as an example of the stowaway pathway, this species being translocated as eggs and larvae within any small amount of standing water. Water within used tyres or ornamental plants (lucky bamboo *Dracaena* spp.) is a cause of the trans-continental introduction of *A. albopictus* to Europe, North America, Africa and Australia (e.g. Reiter 1998). Short-distance dispersal seems to be limited to passive transport by cars and trucks, or movement of infested tyres and plants (Scholte and Schaffner 2007). Establishment in other parts of Europe is very likely within the next decades, supported by climate change (Schaffner et al. 2009). *Aedes albopictus* is a vector of several viruses (e.g. Dengue, Chikungunya, West Nile) and of increasing relevance for Europe (Scholte and Schaffner 2007, van der Weijden et al. 2007). The movement of used tyres is also likely to be responsible for the most recently introduced mosquito species, *Ochlerotatus atropalpus*, native to North America and detected in several European countries (France, Italy, Netherlands), where it was subsequently eradicated (Scholte et al. 2009).

Many insects are attracted to light and most transport hubs (airports, seaports) are illuminated during night-times, increasing the probability of translocation with vehicles after boarding a vector. For example, it is speculated that the attraction to light facilitates the repeated introduction of adult *Diabrotica virgifera* with aircrafts from

North America to Europe, because of regular "first" records of the species in the vicinity of airports. From there the species spreads unaided depending on habitat (maize fields) availability.

Ants (Formicidae) are among the most invasive organisms globally, particularly hazardous on oceanic islands (e.g. Holway et al. 2002, Lach and Hooper-Bùi 2010). Entire colonies with gynes and workers may be translocated as stowaways with soil and litter accompanying ornamental plants, with logs or with other commodities offering shelter. The majority of introduced ants in the USA have been detected on plant material (Suarez et al. 2005). Some of the characteristic traits of tramp ants, e.g. preference for disturbed habitats, polygyny, budding, small body size, support successful translocation and subsequent establishment around the globe (e.g. McGlynn 1999). In Europe, the Argentine ant *Linepithema humile* and the garden ant *Lasius neglectus* are currently considered to be of prime importance (see Kenis and Branco, chapter 5). Whereas the former was introduced as a stowaway with unknown commodities to Europe (Madeira and mainland Portugal) in the 19th century (Wetterer et al. 2009), the origin (likely Asia Minor), pathway and vector (eventually contaminant of garden soil) and successful secondary spread of the latter are still under debate (Ugelvig et al. 2008).

Two more examples of Hymenoptera, initially introduced as stowaways, are the oriental mud dauber *Sceliphron curvatum* and the Asian hornet *Vespa velutina*. The former was introduced in the late 1970s via air cargo from Central Asia to Austria and produces conspicuous mud nests in which paralysed spiders are provisioned as food supply for the developing larvae (Schmid-Egger 2004). The latter was only recently detected in France, probably introduced with pieces of pottery from China (Villemant et al. 2006). These two species have subsequently spread rapidly, unaided, and may be of increasing relevance to native sphecids, hornets and honeybees.

3.3.4. Corridors: Like a rolling stone

The corridor pathway highlights the role transport infrastructures play in the introduction of alien species; shipping canals are the most important example. Gilbert et al. (2004) have shown that the spread of *Cameraria ohridella* in Germany was related to the highway routes, Pekar (2002) argues that the spread of the spider *Zodarion rubidum* was facilitated by the railway system and there is anectodal evidence for repeated northwards transport of the flightless Southern Oak Bush Cricket (*Meconema meridionale*) and the Speckled Bush-Cricket (*Leptophyes punctatissima*) with cars along highways from Southern Europe. Although infrastructure networks undoubtedly contribute to the distribution of alien terrestrial arthropod species in Europe, it seems to be of subordinate relevance and is often intermingled with the contaminant/stowaway pathway.

3.3.5. Unaided: One day I'll fly away

The unaided pathway describes leading-edge dispersal, that means situations where spread results in alien species arriving in a new region from a donor region where it is also alien. This holds true for many alien arthropods occurring in the wild in Europe, being introduced once and spreading after successful establishment. Several examples were mentioned in the chapters above, although this is not reflected in the DAISIE-database (Table 3. 2). Unaided spread often follows initial introduction by one of the other pathways into Europe, although long-distance dispersal events may contribute to the distribution patterns and accelerate rates of spread, as shown for the horse chestnut leafminer *Cameraria ohridella* in Germany and France (Gilbert et al. 2004, 2005). The chestnut gall wasp *Dryocosmus kuriphilus* was introduced with infested plant material from China to Italy and is now spreading unaided to neighbouring countries, but may also bridge larger distances with transport of infested plant material.

Dispersal capacities of arthropods can be impressively high. The conifer seed bug *Leptoglossus occidentalis* and the Harlequin ladybird *Harmonia axyridis* spread over much of Europe within just a decade (e.g. Lis et al. 2008, Rabitsch 2008, Brown et al. 2008) presumably on their own wings. In addition, repeated and independent introductions from the area of origin and/or secondary introductions from the alien range over long distances undoubtedly occur, but such events are difficult to prove and require specific techniques (e.g. molecular biology) (e.g. *Diabrotica virgifera* – Miller et al. 2005, Ciosi et al. 2008).

Controversy surrounds the definition of the alien status of species extending their range due to recent anthropogenic climate change. As long as they utilize the beforementioned pathways, e.g. are translocated with vehicles, but then find suitable climate conditions to establish populations, they should be considered alien. If a species extends its range unaided, but only colonizes disturbed or secondary habitats under strong human influence, such species may be considered as alien. Particularly in arthropods, however, it is sometimes difficult or even impossible, to unambiguously identify the boundaries of the natural range of a species. Historic introductions of today's cosmopolitan species, taxonomic impediment and the lack of recording schemes for most groups cause a high degree of uncertainty in the delimitation of the native range of some species. Host plant distribution, habitats, and molecular techniques may serve as a clue for disentangling factors (e.g. Kavar et al. 2006, Valade et al. 2009).

Unaided dispersal is also often assumed for modelling rates of spread of alien species. Liebhold and Tobin (2008) provided examples for the radial rate of spread in alien insects, which span from 1 to 500 km year^{-1}. In Europe, the western flower thrips *Frankliniella occidentalis* stays ahead with up to 249 km year^{-1} (Kirk and Terry 2003). However, in many if not most cases, additional pathways including long-distance dispersal or at least a combined stratified dispersal need to be taken into account for more realistic scenarios of spread (e.g. Gilbert et al. 2004 for the horse chestnut leafminer *Cameraria ohridella*).

3.4. Future trends and management

There is no reason to assume a decrease in people's movements and restrictions in the transport of goods in the near future. Biological homogenization will tie continents and biodiversity, increasing species richness locally and decreasing it globally; the rate of change will be much more rapid than the hypothesised formation of Neopangaea (Scotese 2001). The ultimate consequences of such a process for the functioning of ecosystems and their services to mankind are far from being well understood.

There is a spatiotemporal signal in the relevance of pathways and vectors. Whereas soil was used as ship ballast in earlier days of European colonization (e.g. Vazquez and Simberloff 2001) this was replaced by ballast water in later years. With the construction of bigger and faster ships, even more organisms were translocated rapidly and with the advent of aircrafts this rate was yet further accelerated. Fast transit enables more species to survive transport and subsequently establish successfully in new regions. In addition, continental, land-locked areas became easily accessible (Mack 2003). Asia has recently gained increasing relevance as a country of export globally (Roques 2010) and as a donor region of alien species, particularly for insects associated with woody plants introduced to Europe (Roques et al. 2009). New trends in the ornamental trade by changed consumer behaviour has created new markets. Only two decades ago, bonsais were rare in European households, but have become a recent fashion; sales are increasing in most areas. Generally, the horticultural/ornamental pathway is of paramount significance for the alien arthropods of Europe (Kenis et al. 2007, Table 3. 2) and there is ample scope for enhancing existing plant protection services (e.g. by increasing personnel at points of entry) and providing best-practice guidance to the ornamental trade industry. It has been shown, however, that interception and establishment data of alien insects for Europe differ significantly (Kenis et al. 2007, Roques 2010). This discrepancy may eventually be explained by the changed relevance of pathways and time-lag phenomena (Crooks 2005). In any case, it demonstrates that additional endeavours are necessary to abate undesirable effects on ecology and economy.

Import and export of goods follows economic rules and global trade mirrors biological invasion patterns (e.g. Levine and D'Antonio 2003, Taylor and Irwin 2004, Kobelt and Nentwig 2008, Westphal et al. 2008, Roques et al. 2009). Chiron et al. (2009) showed such a pattern for bird introductions on both sides of the "iron curtain" in Europe and it is expected that a similar pattern will be found for arthropods. However, information on introduction dates, number of propagules, etc. are usually lacking for arthropod invasions, so that such analyses are difficult to achieve.

Anthropogenic climate change acts upon several levels of biological invasions (e.g. Walther et al. 2009, Thomas and Ohlemüller 2010). It may directly change the realized climatic niche of species, cause habitat shifts (e.g. stepping-stone scenarios) and range shifts in latitude and altitude. Ødegaard and Tømmerås (2000) showed that eight out of 25 alien ground-beetle species used compost heaps as stepping-stones for subsequent establishment in the wild in northern Europe. Global climate change, however, may further act indirectly in changing trade and consumer habits, influencing invasion pathways and vectors by creating new opportunities and depleting traditional routes.

Species-specific eradication plans are a legally binding obligation in the plant health sector and – to some extent – also in the human and veterinary medical sectors. Regulation and harmonization in Europe, however, lags far behind other regions (Hunt et al. 2008) and this is even worse for species of environmental concern. Thinking of arthropods as a mega-diverse group it is highly likely that numbers and impacts of alien species will increase worldwide.

For invasive species management, it is pivotal to tackle pathways, especially in the case of small and unintentionally translocated arthropod species. For example, Skarpass and Økland (2009) proposed measures of how to reduce introduction risk of bark beetles with timber imports. Whereas considerable knowledge has been accumulated for marine pathways, one has to conclude, in agreement with Lockwood et al. (2007), that surprisingly little information is available on the exact magnitude, direction and variation of terrestrial pathways. This is especially true for Europe, where targeted research on invasion pathways should be encouraged. Following identification of the most important pathways, relevant vectors need to be thoroughly tested for their likelihood of interception (e.g. quarantine) or disruption (e.g. import ban or special obligatory and certified treatments) aiming at reducing propagule pressure. There are different options for action to be taken between maximal prevention at border controls and free trade. However, it has to be assumed that “vector management serves as a filter and not as a wall to exotic species” (Carlton and Ruiz 2005: 48).

Anoplophora species provide instructive examples of how obligatory management actions are dealt with in practice in Europe. The reasonable goal of complete eradication is hampered by the implementation of national legislations, by costs borne by individual countries, and repeated introductions as a consequence of the single market policy. A united Europe should opt for better coordination, the polluter-pays-principle, an alien emergency fund, and clear responsibilities. Ultimately, a dedicated independent agency is necessary to deal effectively with biological invasions in Europe (Hulme et al. 2009).

References

Alphey L, Benedict M, Bellini R, Clark GG, Dame DA, Service MW, Dobson SL (2009) Sterile-Insect Methods for Control of Mosquito-Borne Diseases: An Analysis. *Vector-borne and Zoonotic Diseases*, doi:10.1089/vbz.2009.0014

Alyokhin A (2009) Colorado potato beetle management on potatoes: current challenges and future prospects. In: Tennant P, Benkeblia N (Eds) *Potato II.* Fruit, Vegetable and Cereal Science and Biotechnology 3: 10–19.

Aukema B, Loomans A (2005) *Orius laevigatus* in the Netherlands (Heteroptera, Anthocoridae). *Nederlandse Faunistische Mededelingen* 23: 125–127.

Babendreier D (2007) Pros and Cons of Biological Control. In: Nentwig W (Ed) *Biological Invasions*. Ecological Studies 193: 403–418.

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, et al. (2008) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *BioControl* 53: 5–21.

Carlton JT, Ruiz GM (2005) Vector science and integrated vector management in bioinvasions ecology: conceptual frameworks. In: Mooney HA, Mack RN, McNeely JA, Neville LE, Schei PJ, Waage JK (Eds) *Invasive Alien Species. A New Synthesis*. Scope 63, Island Press, Washington, 36–58.

Chiron F, Shirley S, Kark S (2009) Behind the iron curtain: Socio-economic and political factors shapes exotic bird introdurctions into Europe. *Biological Conservation*, doi 10.1016/j.biocon.2009.10.021

Ciosi M, Miller NJ, Kim KS, Giordano R, Estoup A, Guillemaud T (2008) Invasion of Europe by the western corn rootworm, *Diabrotica virgifera virgifera*: multiple transatlantic introductions with various reductions of genetic diversity. *Molecular Ecology* 17: 3614–3627.

Coffey MF (2007) Parasites of the Honeybee. Teagasc, Crops Research Centre, Oak Park, Carlow, 81 pp.

Crooks JA (2005) Lag times and exotic species: the ecology and management of biological invasions in slow-motion. *Ecoscience* 12: 316–329.

Galil B, Gollasch S, Minchin D, Olenin S (2009) Alien marine biota of Europe. In: DAISIE (Eds) *Handbook of Alien Species in Europe*. Springer, Dordrecht, 93–104.

García-Berthou E, Alcaraz C, Pou-Rovira Q, Zamora L, Coenders G, Feo C (2005) Introduction pathways and establishment rates of invasive aquatic species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences* 62: 453–463.

Gaston KJ, Jones AG, Hanel C, Chown SL (2003) Rates of species introductions to a remote oceanic island. *Proceedings of the Royal Society London* 270: 1091–1098.

Genovesi P, Bacher S, Kobelt M, Pascal M, Scalera R (2009) Alien mammals of Europe. In: DAISIE (Eds) *Handbook of Alien Species in Europe*. Springer, Dordrecht, 119–128.

Gilbert M, Gregoire J-C, Freise JF, Heitland W (2004) Long-distance dispersal and human population density allow the prediction of invasive patterns in the horse chestnut leafminer *Cameraria ohridella*. *Journal of Animal Ecology* 73: 459–468.

Gilbert M, Guichard S, Freise J, Grégoire J-C, Heitland W, Straw N, Tilbury C, Augustin S (2005) Forecasting *Cameraria ohridella* invasion dynamics in recently invaded countries: from validation to prediction. *Journal of Applied Ecology* 42: 805–813.

Gillespie RG, Roderick GK (2002) Arthropods on islands: colonization, speciation, and conservation. *Annual Review of Entomology* 47: 595–632.

Haack RA, Hérard F, Sun J, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorned beetle: a worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Higes M, Martin-Hernández R, Garrido-Bailón E, González-Porto AV, Garía-Palencia P, Meana A, del Nozal MJ, Mayo R, Bernal JL (2009) Honeybee colony collapse due to *Nosema ceranae* in professional apiaries. *Environmental Microbiology Reports* 1(2): 110–113.

Hoegh-Guldberg O, Hughes L, McIntyre S, Lindenmayer DB, Parmesan C, Possingham HP, Thomas CD (2008) Assisted colonization and rapid climate change. *Science* 321: 345–346.

Holway DA, Lach L, Suarez AV, Tsutsui ND, Case TJ (2002) The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics* 33: 181–233.

Howarth FG (1991) Environmental impacts of classical biological control. *Annual Review of Entomology* 36: 485–509.

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46: 10–18.

Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I et al. (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. *Journal of Applied Ecology* 45: 403–414.

Hulme PE, Pyšek P, Nentwig W, Vilá M (2009) Will threat of biological invasions unite the European Union? *Science* 324: 40–41.

Hunt EJ, Kuhlmann U, Sheppard A, Qin T-K, Barratt BIP, et al. (2008) Review of invertebrate biological control agent regulation in Australia, New Zealand, Canada and the USA: recommendations for a harmonized European system. *Journal of Applied Entomology* 132: 89–123.

Ings TC, Ward NL, Chittka L (2006) Can commercially imported bumble bees out-compete their native conspecifics? *Journal of Applied Ecology* 43: 940–948.

Jensen AB, Palmer KA, Boomsma JJ, Pedersen BV (2005) Varying degrees of *Apis mellifera ligustica* introgression in protected populations of the black honeybee, *Apis mellifera mellifera*, in northwest Europe. *Molecular Ecology* 14: 93–106.

Kavar T, Pavlovčič P, Sušnik S, Meglič V, Virant-Doberlet M (2006) Genetic differentiation of geographically separated populations of the southern green stink bug *Nezara viridula* (Hemiptera: Pentatomidae). *Bulletin of Entomological Research* 96: 117–128.

Kenis M, Rabitsch W, Auger-Rozenberg M-A, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Kiritani K, Yamamura K (2003) Exotic insects and their pathways for invasion. In: Ruiz GM, Carlton JT (Eds) *Invasive Species. Vectors and Management Strategies.* Island Press, Washington, 44–67.

Kirk WDJ, Terry LI (2003) The spread of the western flower thrips *Frankliniella occidentalis* (Pergrande). *Agricultural and Forest Entomology* 5: 301–310.

Klee J, Besana AM, Genersch E, Gisder S, Nanetti A et al. (2007) Widespread dispersal of the microsporidium *Nosema ceranae*, an emergent pathogen of the western honey bee, *Apis mellifera*. *Journal of Invertebrate Pathology* 96: 1–10.

Kobelt M, Nentwig W (2008) Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Lach L, Hooper-Bùi M (2010) Consequences of ant invasions. In: Lach L, Parr CL, Abbott KL (Eds) *Ant Ecology*. Oxford Univ. Press, Oxford, 261–286.

Levine JM, D'Antonio CM (2003) Forecasting biological invasions with increasing international trade. *Conservation Biology* 17: 322–326.

Levinson HZ, Levinson, AR (1994) Origin of grain storage and insect species consuming desiccated food. *Anzeiger für Schädlingskunde* 67: 47–60.

Liebhold AM, Tobin PC (2008) Population ecology of insect invasions and their management. *Annual Review of Entomology* 53: 387–408.

Lis JA, Lis B, Gubernator J (2008) Will the invasive western conifer seed bug *Leptoglossus occidentalis* Heidemann (Hemiptera: Heteroptera: Coreidae) seize all of Europe? *Zootaxa* 1740: 66–68.

Lockwood JL, Hoopes MF, Marchetti MP (2007) Invasion Ecology. Blackwell Publ., Oxford, 304 pp.

Mack RN (2003) Global plant dispersal, naturalization, and invasion: pathways, modes, and circumstances. In: Ruiz GM, Carlton JT (Eds) *Invasive Species. Vectors and Management Strategies*. Island Press, Washington, 3–30.

McCullough DG, Work TT, Cavey JF, Liebhold AM, Marshall D (2006) Interceptions of nonindigenous plant pests at US ports of entry and border crossings over a 17-year period. *Biological Invasions* 8: 611–630.

McGlynn TP (1999) The worldwide transfer of ants: geographical distribution and ecological invsions. *Journal of Biogeography* 26: 535–548.

Miller N, Estoup A, Toepfer S, Borguet D, Lapchin L, Deirid S, Kin KS, Reynaud P, Furlan L, Guillemaud T (2005) Multiple Transatlantic introductions of the western corn rootworm. *Science* 310: 992.

Moritz RFA, Härtel S, Neumann P (2005) Global invasions of the western honeybee (*Apis mellifera*) and the consequences for biodiversity. *Ecoscience* 12: 289–301.

Murphy ST, Evans HC (2009) Biological control of invasive species. In: Clout MN, Williams PA (Eds) *Invasive Species Management. A Handbook of Principles and Techniques*. Oxford Univ. Press, Oxford, 77–92.

Nentwig W (2007) Pathways in Animal Invasions. In: Nentwig W (Ed) *Biological Invasions*. Ecological Studies 193: 11–27.

Oates MR, Warren MS (1990) A review of butterfly introductions in Britain and Ireland. Joint Committee for the Conservation of British Insects and WWF, Godalming, 96 pp.

Ødegaard F, Tømmerås BA (2000) Compost heaps – refuges and stepping-stones for alien arthropod species in northern Europe. *Diversity and Distributions* 6: 45–59.

Pekar S (2002) *Zodarion rubidum* Simon 1914: railroad riders? Newsletter of the British Arachnological Society 95: 11–12.

Rabitsch W (2008) Alien True Bugs of Europe (Insecta: Hemiptera: Heteroptera). *Zootaxa* 1827: 1–44.

Ratnieks FLW, Carreck NL (2010) Clarity on Honey Bee Collapse? *Science* 327: 152–153.

Rees D (2004) Insects of Stored Products. CSIRO Publishing, Collingwood, 192 pp.

Reiter P (1998) *Aedes albopictus* and the world trade in used tires, 1988–1995: the shape of things to come? *Journal of the American Mosquito Control Association* 14: 83–94.

Ricciardi A, Simberloff D (2009) Assisted colonization is not a viable conservation strategy. *Trends in Ecology and Evolution* 24: 248–253.

Roques A (2010) Alien forest insects in a warmer world and a globalised economy: impacts of changes in trade, tourism and climate on forest biosecurity. *New Zealand Journal of Forestry Science* 40 suppl: S77–S94.

Roques A, Auger-Rozenberg M-A (2006) Tentative analysis of the interceptions of non-indigenous organisms in Europe during 1995–2004. *EPPO Bulletin* 36: 490–496.

Roques A, Rabitsch W, Rasplus J-Y, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: DAISIE (Eds) The Handbook of Alien Species in Europe. Springer, Dordrecht, 63–79.

Roy HE, Wajnberg E (2008) From Biological Control to Invasion: the Ladybird *Harmonia axyridis* as a Model Species. Springer, 287 pp.

Roy HE, Brown P, Majerus MEN (2006) *Harmonia axyridis*: a successful biocontrol agent or an invasive treat? In: Eilenberg J, Hokkanen H (Eds) *An ecological and societal approach to biological control*. Progress in Biological Control 2: 295–309.

Ruiz GM, Carlton JT (2003) Invasive species. Vectors and Management Strategies. Island Press, Washington, 518 pp.

Sala J, Boix D (2005) Presence of the nearctic water boatman (*Trichocorixa verticalis verticalis* (Fieber, 1851) (Heteroptera, Corixidae) in the Algarve region (S Portugal). *Graellsia* 61: 31–36.

Sammataro D, Gerson U, Needham G (2000) Parasitic mites of honey bees: life history, implications, and impact. *Annual Review of Entomology* 45: 519–548.

Schaffner F, Hendrickx G, Scholte EJ, Medlock J, Angelini P, Ducheyne E (2009) Development of *Aedes albopictus* risk maps. TigerMaps project report. European Centre for Disease Prevention and Control, Stockholm, 52 pp.

Schmid-Egger C (2004) *Sceliphron curvatum* (F. Smith 1870) in Europa mit einem Bestimmungsschlüssel für die europäischen und mediterranen *Sceliphron*-Arten (Hymenoptera, Sphecidae). *Bembix* 19: 7–28.

Schmitt T, Cizek O, Konvicka M (2005) Genetics of a butterfly relocation: large, small and introduced populations of the mountain endemic *Erebia epiphron* silesiana. *Biological Conservation* 123: 11–18.

Scholte EJ, Schaffner F (2007) Waiting for the tiger: establishment and spread of the *Aedes albopictus* mosquito in Europe. In: Takken W, Knols BGJ (Eds) *Emerging pests and vector-borne diseases in Europe*. Wageningen Academic Publ., Wageningen, 241–260.

Scholte EJ, Den Hartog W, Braks M, Reusken C, Dik M, Hessels A (2009) First report of a North American invasive mosquito species *Ochlerotatus atropalpus* (Coquillett) in the Netherlands, 2009. *Euro Surveillance* 14(45) 19400.

Scotese R (2001) Atlas of Earth History, The Paleomap Project. Arlington, Texas, 52 pp.

Skarpass O, Økland B (2009) Timber import and the risk of forest pest introductions. Journal of Applied Ecology 46: 55–63.

Suarez AV, Holway DA, Ward PS (2005) The role of opportunity in the unintentional introduction of nonnative ants. *Proceedings of the National Academy of Sciences* 102: 17032–17035.

Taylor BW, Irwin RE (2004) Linking economic activities to the distribution of exotic plants. *Proceedings of the National Academy of Sciences* 101: 17725–17730.

Thomas CD, Ohlemüller R (2010) Climate change and species' distributions: an alien future? In: Perrings C, Mooney H, Williamson M (Eds) *Bioinvasions & Globalization. Ecology, Economics, Management, and Policy*. Oxford University Press, Oxford, 19–29.

Thomas DT, Donnelly CA, Wood RJ, Alphey LS (2000) Insect population control using a dominant, repressible, lethal genetic system. *Science* 287: 2474–2476.

Ugelvig LV, Drijfhout FP, Kronauer DJC, Boomsma JJ, Pedersen JS, Cremer S (2008) The introduction history of invasive garden ants in Europe: Integrating genetic, chemical and behavioural approaches. *BMC Biology* 6(11): 1–14.

Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkanic origin for the highly invasive Horse-Chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). *Molecular Ecology* 18: 3458–3470.

Van der Weijden WJ, Marcelis RAL, Reinhold W (2007) Invasions of vector-borne diseases driven by transportation and climate change. In: Takken W, Knols BGJ (Eds) *Emerging pests and vector-borne diseases in Europe*. Wageningen Academic Publ., Wageningen, 439–463.

Van Lenteren JC, Bale J, Bigler F, Hokkanen HMT, Loomans AJM (2006) Assessing risks of releasing exotic biological control agents of arthropod pests. *Annual Review of Entomology* 51: 609–634.

Vazquez DP, Simberloff D (2001) Taxonomic selectivity in surviving introduced insects in the United States. In: Lockwood JL, McKinney ML (Eds) *Biotic Homogenization*. Kluwer Acad. Pl., New York, 103–124.

Vierbergen G (2001) Occurrence of glasshouse Thysanoptera in the open in the Netherlands. In: Marullo R, Mound L (Eds) *Thrips and Tospoviruses*: Proceedings of the 7th International Symposium on Thysanoptera. CSIRO, Canberra, 390 pp.

Villemant C, Haxaire J, Streito J-C (2006) Premier bilan de l'invasion de *Vespa velutina* Lepeletier en France (Hymenoptera, Vespidae). *Bulletin de la Société entomologique de France* 111: 535–538.

Walther G-R, Roques A, Hulme PE, Sykes MT, et al. (2009) Alien species in a warmer world: risks and opportunities. *Trends in Ecology and Evolution* 24: 686–693.

Westphal MI, Browne M, MacKinnon K, Noble I (2008) The link between international trade and the global distribution of invasive alien species. *Biological Invasions* 10: 391–398.

Wetterer J, Wild AL, Suarez AV, Roura-Pascual N, Espadaler X (2009) Worldwide spread of the Argentine ant, *Linepithema humile* (Hymenoptera: Formicidae). *Myrmecological News* 12: 187–194.

Wilson JRU, Dormontt EE, Prentis PJ, Lowe AJ, Richardson DM (2009) Something in the way you move: dispersal pathways affect invasion success. *Trends in Ecology and Evolution* 24: 136–144.

Witzenberger K, Hochkirch A (2008) Genetic consequences of animal translocations: A case study using the field cricket, *Gryllus campestris* L. Biological Conservation 141: 3059–3068.

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RESEARCH ARTICLE

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Invaded habitats Chapter 4

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Abstract
More than 65% (1040 species) of arthropod species alien *to* Europe are associated with human-made habitats, especially parks and gardens, human settlements and agricultural lands, whereas woodlands are yet colonized by less than 20% of the alien fauna, which still has a negligible representation in the other natural and semi-natural habitats. Large differences in habitat affinity are observed between alien taxonomic groups. Phytophagous species are predominant among aliens, representing 47.2% of species alien *to* Europe.

Keywords
alien, arthropod, habitat, Europe, level of invasion, urban, semi-urban

4.1 Introduction

The lack of a general assessment on the level of habitat invasion in Europe has up to now limited the possibilities of evaluating the risks arthropod invaders pose to different habitats. Such an assessment is a fundamental component of early detection and identification of those environments that are more prone to invasion, that will provide a baseline for optimizing actions to prevent, monitor and control invasion (Pyšek et al. 2010). For that reason, here we present a synthesis of the data on habitat preference of terrestrial arthropods alien *to* Europe compiled from chapters 7-13 of this book, providing an overview of which habitats are most invaded in Europe, and to assess differences among alien taxa in terms of habitat affinity.

We compared the numbers of established alien species occurring in 11 European habitats defined according to the European Nature Information System, level 1 (EUNIS) (Davies et al. 2004). This standard classification of European habitats has been chosen as a platform in several different studies on biological invasions in Europe (Chytrý et al. 2008, Daisie 2009, Pyšek et al. 2010). In this classification, a 'habitat' is defined as '*a place where plants or animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality, etc.) and secondarily by the species of plants and animals that live there*' (Davies *et al.*, 2004). Appendix II presents the different habitat types used throughout the taxa chapters. For more convenience, our analysis grouped them into the following broad categories roughly corresponding to the level I of EUNIS: coastal habitats (EUNIS class B); wetlands and riparian habitats (C); mires (D); grasslands (E); heathlands, hedgerows and shrub plantations (F); woodlands (G); cultivated habitats (I1); parks and gardens (we grouped the classes I2 and X11, X22, X23, X24, X25); and urban settlements (J) to which we added a specific code for greenhouses (J100). These broad categories may not precisely reflect the habitat(s) actually colonized by some species, but their use standardizes comparisons between very different taxa such as arthropods, plants and vertebrates.

The habitats in the system adopted here differ considerably in the number of alien arthropod species they contain. Aliens show a strong affinity for the habitats intensively disturbed by human activities (Figure 4.1.). Considering all established alien terrestrial arthropods, the highest percentage occurs in parks and gardens (500 out of the 1590 alien species found in Europe- 31.4%) and in human settlements (31.0 %), whilst slightly less occur in cultivated habitats, which host 29.7% of these alien species. Altogether, human-made habitats host 65.4% (1040 species) of the fauna of arthropods alien *to* Europe, most of these species being likely to occur in several different habitats. In contrast, less than 10% of the alien species have yet colonized natural and semi-natural habitats such as wetlands, riparian habitats, grasslands and heathlands, and less than 20% occur in woodlands and forests (Figure 4.1). These results confirm the analysis of Roques et al. (2009) which relied on a lower number of alien arthropod species. Pyšek et al. (2010) also stated that alien plants are mostly found in human-made, urban or cultivated habitats, unlike vertebrates, which are more evenly distributed among habitats, the most invaded of which are aquatic and riparian habitats, woodland and cultivated land.

Some habitats are differentially preferred by certain taxonomic groups (Table 4.1). For instance, many alien species are pests of ornamental plants in parks and gardens. In particular, mites are an important group attacking urban trees, shrubs and flowering plants. More than 40% of alien mites are observed in this habitat. Similarly, alien hemipterans, especially aphids, and lepidopterans have colonized parks and gar-

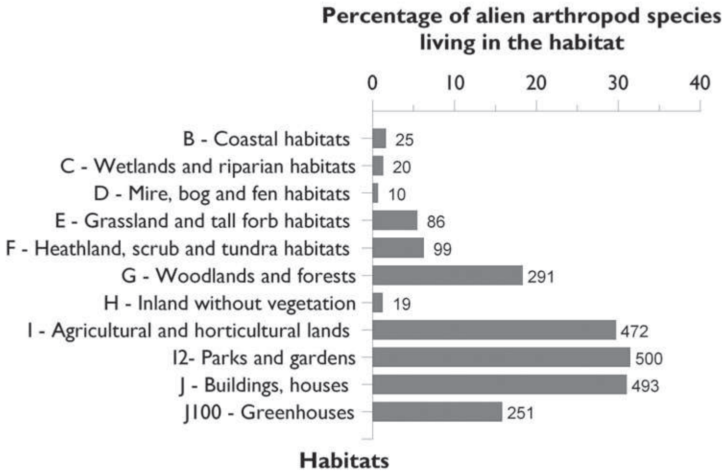

Figure 4.1. Main European habitats colonized by the 1590 species of terrestrial arthropods alien *to* Europe. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

dens effectively, 78.9% and 56.7% of their species being observed there, respectively (Table 4.1).

Built-up, industrial and other artificial habitats are invaded to a high degree by spiders. Indeed, more than 90% of the alien spiders are found in buildings. Psocoptera is another well-represented group in this habitat with 81.6% of its alien species in Europe occurring there, as is Phthiraptera (67.7%) and Coleoptera (57.3%), a number of species of the latter group being associated with stored products. By contrast, alien Hymenoptera are mostly present in agricultural lands which are colonized by 65.0% of the alien species in this taxon, probably in relation with the multiple parasitoid releases that have occurred for biological control purposes. Greenhouses constitute another important man-made habitat type, which hosts most alien myriapods (64.7%) and thrips (55.8%).

Why do most introduced terrestrial arthropods apparently stay confined to human- modified habitats in their alien range of distribution? Several ecological conditions may be considered: i) disturbed urban and semi-urban areas may have a lower resistance to aliens, especially because of a lower pressure of potential natural enemies and, for phytophagous aliens, less vigorous host plants; ii) some species may prefer human-related habitats in their native range and are thus more likely to be carried into a new area by human transport, than species living in natural environments (Kenis et al. 2007). For instance, exotic ornamental plants are generally used in man-made habitats such as nurseries, parks and gardens and roadside plantings and shelter belts. Most alien phytophagous species introduced alongside these ornamentals remain as yet strictly associated with their original, exotic host (46.4% in Europe; Roques, 2008). They have not so far colonized native trees, and thus they develop only in parks and gardens and in hedgerows where such exotic plants are planted. A striking example is that of the horse-chestnut leaf-mining moth *Cameraria ohridella*, which in its area of origin, the southern Balkans, lives in mountain ravines, whereas in its introduced area of Central and Western Europe, preferentially colonizes urban parks and gardens where its host tree has been extensively planted (Valade et al. 2009).

However, there could be a time-lag between the introduction to human habitats and adaptation and spread to natural habitats. Therefore, many alien species currently confined to human-made habitats should be monitored for their potential spread to natural areas (Roques et al. 2009). For instance, species such as the Asian longhorn beetles, *Anoplophora* spp., (Coleoptera, Cerambycidae) have the potential to live in urban areas, in cultivated lanes (e.g. those planted with poplars) as well as in natural forests where potential host plants occur. However, dispersal from man-made habitats to natural forests appears to be a slow process. For the first twenty-two years since its arrival in North America, *A. glabripennis* was restricted to trees in urban areas, but in 2008, it was found in natural forests dominated by *Acer* trees (Haack et al. 2010).

Finally, phytophagous species are predominant among the alien terrestrial arthropods, representing 47.2% (751 of 1590) of alien species to Europe, Parasitoids and predators only account for 32.6 % (518 spp.) whilst detritivores represent 20.8% (331 spp.). A few species exhibit several phytophagous guilds, whilst the habits of just 19 species are still unknown.

References

Chytrý M, Maskell LC, Pino J, Pyšek P, Vilà M, Font X, Smart SM (2008) Habitat invasions by alien plants: a quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. *Journal of Applied Ecology*, 45: 448–458.

DAISIE (2009) *Handbook of alien species in Europe*. Dordrecht: Springer. 399 pp.

Davies CE, Moss D, Hill MO (2004) EUNIS habitat classification, revised 2004. Paris: European Environment Agency, Copenhagen and European Topic Centre on Nature Protection and Biodiversity.

Haack RA, Hérard F, Sun JH, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorn beetle: A worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Kenis M, Rabitsch W, Auger-Rozenberg M-A, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Pyšek P, Bacher S, Chytrý M, Jarošík V, Wild J, Celesti-Grapow L, Gassó N, Kenis M, Lambdon P, Nentwig W, Pergl J Roques A, Sádlo J, Solarz W, Vilà M, Hulme PE (2010) Contrasting patterns in the invasions of European terrestrial and freshwater habitats by alien plants, insects and vertebrates. *Global Ecology and Biogeography* 19: 317–331.

Roques A. (2008). The pan-European inventory of alien species established on trees on shrubs, a tool for predicting taxa and ecosystems at risk -final results of the DAISIE project. In *Alien invasive species and international trade, 2nd meeting of IUFRO Working Unit 7.03.12,* *May 26-30, 2008, National Conservation Training Center, Shepherdstown, WV, USA.* Available at [http://www.forestry.gov.uk/pdf/IUFRO_ Shepherdstown_Roques_Sheperdstown_end.pdf/FILE/IUFRO_Shepherdstown_ Roques_Sheperdstown_end.pdf]

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: Daisie (Ed) *Handbook of Alien Species in Europe*. Dordrecht: Springer, 63–79.

Valade R, Kenis M, Hernandez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive Horse-Chestnut leaf miner Cameraria ohridella (Lep. Gracillariidae). *Molecular Ecology* 18: 3458–3470.

Table 4.1. Comparative colonization of European habitats by the different taxonomic groups of terrestrial arthropods alien to Europe. The total number of established alien species observed in each habitat is figured. A species may have colonized several habitats. The percentage of species observed in the habitat with regard to the total number of alien species in the taxonomic group in Europe (last line) is given between brackets. 'Polyneoptera' includes Blattodea, Dermaptera, Isoptera, Orthoptera and Phasmatodea (see Chapter 13.3).

EUNIS categories	Crustacea	Myriapods	Aranea	Acari	Coleoptera	Diptera	Hemiptera	Hymenoptera	Lepidoptera	Phthiraptera	Polyneoptera[1]	Psocoptera	Siphonaptera	Thysanoptera	Zygentoma/ Collembolla
A- Marine habitats	-	-	-	-	-	-	-	-		-		-	-	-	-
B- Coastal habitats	-	3 (8.8)	-		12 (3.0)	6 (6.1)	2 (0.6)	-	2 (2.1)	-		-	-	-	-
C- Riparian habitats	-	-	-	6 (5.9)	5(1.3)	4 (4.1)	1 (0.3)	3 (1.0)	-	1 (3.2)		-	-	-	-
D- Mires, bogs, fens	-	1 (2.9)	-	-	3 (0.8)	4 (4.1)	1 (0.3)	1 (0.3)	-	-		-	-	-	-
E- Grasslands	-	2 (5.9)	6 (12.8)	2 (2.0)	24 (6.0)	6 (6.1)	19 (6.0)	8 (2.7)	3 (3.1)	4 (12.9)	7 (18.9)	-	2 (28.6)	3 (5.8)	-
F- Heathlands	-	2 (5.9)	6 (12.8)	9 (8.8)	39 (9.8)	4 (4.1)	16 (5.0)	4 (1.3)	13 (13.4)	1 (3.2)	2 (5.4)	-	1 (14.3)	2 (3.8)	-
G- Woodlands	3 (17.6)	4 (11.8)	6 (12.8)	10 (9.8)	77 (19.3)	12 (12.2)	61 (19.2)	74 (24.9)	19 (19.6)	8 (28.6)	1 (2.7)	12 (19.0)	2 (28.6)	2 (3.8)	-
H- Bare lands	-	2 (5.9)	6 (12.8)	-	2 (0.5)	1 (1.0)	1 (0.3)	2 (0.7)	2 (2.1)	-	1 (2.7)	2 (3.2)	-	-	-
I- Cultivated lands	-	3 (8.8)	6 (12.8)	33 (32.4)	87 (21.9)	18 (18.4)	91 (28.6)	193 (65.0)	25 (25.8)	-	7 (18.9)	1 (1.6)	-	7 (13.5)	1 (16.7)
I2/X- Parks, gardens	-	9 (26.5)	-	42 (41.2)	69 (17.3)	17 (17.3)	251 (78.9)	23 (7.7)	55 (56.7)	7 (14.3)	2 (5.4)	8 (12.7)	1 (14.3)	15 (28.8)	1 (16.7)
J- Urban, semi-urban	17 (100.0)	8 (23.5)	43 (91.5)	11 (10.8)	228 (57.3)	25 (25.5)	7 (2.2)	31(10.4)	33 (34.0)	21 (71.4)	20 (54.1)	40 (63.5)	5 (71.4)	1 (1.9)	3 (50.0)
J100 - Greenhouses	-	22 (64.7)	2 (4.3)	13 (12.7)	12 (3.0)	6 (6.1)	80 (25.2)	63 (21.2)	16 (16.5)	-	5 (13.5)	-	-	29 (55.8)	3 (50.0)
Total species	**17**	**34**	**47**	**102**	**398**	**98**	**318**	**297**	**97**	**31**	**37**	**49**	**7**	**52**	**6**

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Impact of alien terrestrial arthropods in Europe Chapter 5

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Abstract

This chapter reviews the effects of alien terrestrial arthropods on the economy, society and environment in Europe. Many alien insect and mite species cause serious socio-economic hazards as pests of agriculture, horticulture, stored products and forestry. They may also affect human or animal health. Surprisingly, there is relatively little information available on the exact yield and financial losses due to alien agricultural and forestry pests in Europe, particularly at continental scale. Several alien species may have a positive impact on the economy, for example parasitoids and predators introduced for the biological control of important pests. Invasive alien arthropods can also cause environmental hazards. They may affect native biodiversity through various mechanisms, including herbivory, predation, parasitism, competition for resource and space, or as vectors of diseases. They can also affect ecosystem services and processes through cascading effects. However, these ecological impacts are poorly studied, particularly in Europe, where only a handful cases have been reported.

Keywords

Biological invasions, economic impact, environmental impact, alien arthropods

5.1. Introduction

Alien insects and other terrestrial arthropods are among the most numerous invaders worldwide. In Europe alone, the update of the DAISIE database (Roques et al. 2009) which is presented in this book considers that 1590 terrestrial arthropod species of non-European origin are established in Europe, including 1390 insects, 47 spiders,102 mites, 34 myriapods and 17 crustaceans. Many others originate from a restricted region in Europe but have invaded other parts of the continent. The establishment and spread of these alien species may have various effects. The best documented impacts are economic, particularly due to agricultural or forest pests (Pimentel et al. 2002a, 2002b). Alien arthropods also impact the environment by affecting populations or communities of native species and by disturb natural ecosystem processes and services (Kenis et al. 2009). They affect human and animal health. Finally, alien organisms have a social impact when they influence human well-being (Binimelis et al. 2007).

In this chapter, we review the socio-economic and environmental impacts caused by alien terrestrial arthropods in Europe. Human and animal health impacts will be considered with socio-economic impacts since they represent measurable economic and social costs. Although the social costs of invasions are often difficult to measure in monetary terms, we could not find a single example of an alien arthropod in Europe that primarily affects human well-being without an additional economic burden.

The impact of alien species is usually considered to be negative. In some cases, however, the introduction of an alien arthropod may have a positive impact on the economy or the environment, for example when an exotic biological control agent successfully controls a pest, reducing yield losses or preventing the use of pesticides. Positive impacts of alien arthropods will also be considered in this review.

The review is partly based on the DAISIE database, a pan-European inventory of alien species commissioned by the European Union (Hulme et al. 2009). When building the list of alien organisms in Europe, experts were asked whether the organism had an economic or environmental impact in a particular country. Although their judgement provides valuable opinions, these have to be taken with caution because they were largely subjective and often unsupported by published references.

5.2. Socio-economic impact

The economic impact of alien species has been described as the consequence of an interaction between the invader and economically valuable indigenous species (Williamson 1996). Alien arthropods can affect the economy and society in various ways, through their impact on agriculture, horticulture, forestry, stored products, human and animal health, or various services.

Economic impacts can be direct or indirect. Direct economic impacts occur when alien species that affect valuable species or goods cause damage that results in yield losses and increasing production costs. These types of economic impacts are those most often described and can be easily expressed in monetary values (Pimentel et al. 2002a, 2002b). Pest management costs contribute largely to the direct economic impact of alien species. Insect pests imply the yearly application of more than 3000 million kilograms of insecticides globally (Pimentel 2007), a large share of it targeting alien pest species. An alien pest may also cause yield losses in its role as vector of other pests and diseases, through interference with indigenous pollinators or as competitors, parasites or predators of beneficial organisms.

Indirect socio-economic effects associated with the introduction of an alien pest include, among others, restrictions on trade flow, effects on market access, changes in market values, changes to domestic or foreign consumer demand for a product resulting from quality changes, changes in land use and landscape structure, public health concerns, costs associated with research and educational services, societal effects such as unemployment, effects on tourism, etc. Indirect effects are often difficult to evaluate because many of them cannot easily be expressed in monetary terms (Born et al. 2005).

Vilà et al. (2010) estimated from the DAISIE database that 24.2% of the alien invertebrates in Europe have an economic impact. More than a half (51.6%) of the terrestrial arthropods alien to Europe are herbivores and, similarly, about 50% of those with economic impact are phytophagous species. Kenis et al. (2007) found that 40% of the alien insects in Switzerland and Austria had at least one web page describing damage and control methods, suggesting a socio-economic impact. Kenis et al. (2007) also estimated that the rate of native insects reaching pest status in temperate countries is probably much lower than 5%. Alien arthropods are well known for being serious plant pests worldwide. More than half of alien arthropods of economic concern are plant pests, which may directly affect yield losses of a variety of forestry and agricultural crops, such as timber, fruits, vegetables, cereals, ornamentals, etc. Insect pests destroy approximately 14% of all potential food production globally (Pimentel 2007). It is estimated that between 30 and 45% of the insect pests in agriculture and forestry worldwide are of alien origin (Pimentel et al. 2002a, 2002b), despite the fact that they only represent a few percent of the insect fauna.

Economic studies on the impact of alien arthropods worldwide are numerous, but less so in Europe. Born et al. (2005) also stated that most economic analysis on the impacts of alien species has been undertaken outside Europe, particularly in North America, South Africa and Oceania. Below, we discuss the most serious economic alien pests of agriculture, protected horticulture, stored products and infrastructures, forestry and urban trees and human and animal health in Europe. Positive impacts of alien arthropods on the economy are discussed separately.

5.2.1. Outdoor agricultural and horticultural pests

Many alien arthropods affect European agriculture and horticulture, mainly through yield losses and management costs, but also though quarantine measures, market effects and foreign trade impact. Reliable data on average yield and financial losses due to alien agricultural pests are not frequently published, particularly in Europe. This may be partly due to the lack of controlled, replicated experiments in commercial fields required to document such information. Furthermore, crops are often attacked by several pest species and the contribution of yield or monetary loss due to a single species is difficult to assess. Pimentel (2002) has calculated for the British Isles that, since each year arthropods damage or destroy approximately 10% of the crops and 30% of the pests are of exotic origin, alien arthropods cause yield losses of $960 million per year. A similar calculation for the entire European Union would lead to annual economic losses of approximately 10 billion € caused by alien arthropods. This does not include control, eradication or quarantine costs, nor costs linked to foreign trade impact or market effects. The agricultural/horticultural insecticide market represents over one billion € per year in Europe (ECPA 2007), of which probably at least 20 to 30% is to control alien pests.

The first major alien agricultural insect pest that hit the European economy was the American vine phylloxera, *Viteus vitifoliae*, which, in the late 19th century completely destroyed nearly one-third of the French vineyards in the country, i.e. more than 1.000,000 ha, with incalculable economic and social consequences (CABI 2007). The problem was largely solved by replanting European cultivars grafted onto resistant American rootstocks, although some phylloxera biotypes have developed that may overcome the resistance of certain rootstock cultivars.

Another major arthropod that invaded the European fields a while ago is the Colorado potato beetle, *Leptinotarsa decemlineata*. Since its first occurrence in France in 1922, it has spread to most European countries, causing considerable yield losses in potato fields. Nowadays, effective routine control of the beetle has been incorporated into potato cultivation systems and it is difficult to properly assess the economic cost of the beetle alone. In the eastern USA, the cost of controlling infestations averages between US$138 and $368 per hectare but, in this region, infestations are higher than in Europe because of the local development of resistance to the major insecticides (CABI 2007). *Leptinotarsa decemlineata* has not yet invaded the whole of Europe and some countries are still spending significant amounts of money to prevent its entry. For example, in Finland, pre-entry control measures against the beetle cost an average of EUR 171,000 per year in the period from 1999 to 2004 (Heikkilä and Peltola 2006). A cost-benefit analysis showed that the benefit of these protection measures strongly depends on future scenarios, in particular regarding local climatic conditions and agricultural policies.

In the 1990s, the introduction into Europe of the western corn rootworm beetle *Diabrotica virgifera virgifera,* a serious maize pest in North America, generated much attention. A few years after its introduction, mean yield losses in Serbian Maize fields were estimated to be around 30% (Sivcev and Tomasev 2002). Baufelt and Enzian (Baufeld and Enzian 2005) calculated that the potential pecuniary losses in maize due to *D. virgifera virgifera* in a selection of European countries was as high as 147 million €/year, based on a conservative average yield loss of 10%. Consequently, most European countries apply costly regulatory control measures to prevent the pest's establishment in their countries. Nevertheless, in some countries, regulatory control measures may not be economically justified. For example, in UK a cost/benefit analysis showed that, in the absence of a statutory campaign, yield losses of 5% caused by the beetle in maize could have a present value of £0.6 to £2.8 million over 20 years. However, costs of a statutory campaign against the pest over the same period could range from £2.5 to £7.1 million (MacLeod 2006).

Fruit orchards are particularly prone to alien insect invasions. Many of the most serious pests in European orchards are alien, such as the San José scale, *Diaspidiotus perniciosus*, the Mediterranean fruit fly, *Ceratitis capitata*, the oriental fruit moth, *Grapholita molesta*, the citrus leaf miner, *Phyllocnistis citrella*, the woolly whitefly, *Aleurothrixus floccosus*, etc. Some arthropods are harmless by themselves but are vectors of serious diseases, such as the leafhopper *Scaphoideus titanus*, vector of Flavescence dorée in vineyards. These arthropods, and many other alien agricultural and horticultural pests are described in the factsheets (see Chapter 14). Despite their economic importance, there is little information on the exact costs related to orchard pests. However, when data are available, they are impressive. For example, in Israel, Palestine and Jordan, the annual fruit losses due to *C. capitata* were estimated to be about U.S. $365 million, an amount which represents more than half of the total fruit revenue of the area (Enkerlin and Mumford 1997).

5.2.2. Pests of protected horticulture

Most plant pests that occur in greenhouses and other protected environments are of tropical or sub-tropical origin. Some of them also occur on outdoor crops in Southern Europe. Among the most serious alien pests of protected crops in Europe are the leaf miners *Liriomyza huidobrensis* and *L. trifolii*, the whiteflies *Bemisia tabaci* and *Trialeurodes vaporariorum*, the aphids *Aphis gossypii*, *Myzus persicae* and *Macrosiphum euphorbiae,* the western flower thrips *Frankliniella occidentalis* (see factsheets 23, 24, 33, 35, 37 and 78), the citrus mealybug *Planococcus citri* and the moth *Opogona sacchari*. Several of these, particularly aphids, whiteflies and thrips, are vectors of important plant viruses. Mediterranean arthropods such as the lepidopteran defoliator *Cacoecimorpha pronubana*, the leaf mining fly *Liriomyza bryoniae* and the spotted spider mite *Tetranychus urticae* have now invaded protected crops throughout Europe (Brødsgaard and Albajes 1999).

These alien pests cause enormous economic damage to the greenhouse and protected crops industry, through yield losses, control costs, contingency plans, eradication costs or losses in consignments for export. For example, Roosjen et al. (Roosjen et al. 1998) estimated that the annual cost of *F. occidentalis* to the Dutch greenhouse could be US$30 million, plus a further US$19 million from the effects of Tomato spotted wilt tospovirus transmitted by the thrips. An intensive eradication programme carried out to control an outbreak of the melon thrips, *Thrips palmi* in a UK greenhouse in 2000 cost £178,000 (MacLeod et al. 2004). A cost/benefit analysis showed that this eradication programme was four to 19 times cheaper compared with potential losses forecast by modelling the spread and impact of *T. palmi* in glasshouse crops over ten years. In another example, Rautapaa (1984) comparing all the costs caused by exclusion measures (eradication + quarantine) to maintain Finland free from *Liriomyza* *trifolii*, with the costs of living with the pest, obtained ratios 1:3 to 1:13 in favour of eradication/quarantine measures.

5.2.3. Stored product and infrastructure **pests**

In Europe, 113 alien insect species are pests of stored products, feeding on products such as grains, seeds, fruits, fabrics, and wood products. Most are Coleoptera (e.g. Anobiidae, Bostrichidae, Chrysomelidae, Cucujidae, Curculionidae, Dermestidae, Mycetophagidae, Nitidulidae, Ptinidae, Silvanidae and Tenebrionidae), Lepidoptera (mainly Pyralidae; Gelechiidae and Tineidae) and Blattodea (cockroaches). Several alien xylophagous beetles and termites may also seriously damage public infrastructures and domestic impairments, furniture and buildings. Alien stored product and infrastructure pests are usually cosmopolitan insects of tropical or sub-tropical origin, being transported worldwide with their food (Rees 2004).

Both the quantity and quality of the stored products may be affected by pests. An economic evaluation has been carried out for three species in Germany (Reinhardt et al. 2003). The annual costs arising from the two grain beetles *Oryzaephilus surinamensis* and *Rhyzopertha dominica* vary from 11.2 to 35.3 million € and that of the flour moth *Ephestia kuehniella* from 4.6 to 12.3 million €. Considering that these numbers are only for Germany and for three pest species, it is likely that the costs due to the two dozen economically significant alien stored product arthropod pests in Europe exceed 1 billion € per year.

5.2.4. Forestry and urban tree pests

Alien arthropods can have severe economic impacts on forest plantations and urban parks. A total of 438 alien insects are associated with woody plants, representing 28.7% of all European alien species (Roques 2010). So far, European forests have suffered less from invasive arthropods than other continents, and the most important forest pests in Europe are still indigenous species. However, several potentially damaging alien forest pests have recently become established, such as the chestnut gall wasp *Dryocosmus kuriphilus*, the ambrosia beetle, *Megaplatypus mutatus* and the two Asian longhorned beetles *Anoplophora glabripennis* and *A. chinensis* (see factsheets 6, 7, and 17). Exotic trees tend to suffer more from alien pests than native trees (Day and Leather 1997). Forty-seven percent of the alien pest species affecting forest and urban trees are associated mainly or exclusively with exotic tree and shrub species (Roques 2010). For example, eucalyptus trees are particularly prone to damage by invaders from Australia. Nine alien arthropods are presently found in Europe feeding on eucalyptus, including two woodborers, *Phoracantha semipunctata* and *P. recurva,* the eucalyptus snout beetle, *Gonipterus scutellatus*, three psyllids *Ctenarytaina eucaliptii*, *C. spatulata* and *Glycaspis brimblecombi*, two gall wasps *Leptocybe invasa* and *Ophelimus maskelli* and an eriophid mite, *Rhombacus eucaliptii.* In southern Spain, after the first detection of *P. semipunctata* in 1981, the average tree mortality in the subsequent two years was estimated to be about 3%, equivalent to a loss of 6207 ha, despite the costly control measures applied during this period (Gonzalez Tirado 1986). *Gonipterus scutellatus* is considered to cause tree growth losses of up to 30% in Galicia (Mansilla et al. 1996). The arrival of alien forest pests may also have indirect effects on land use and land value. For example, in Portugal, in the years following the arrival of *P. semipunctata*, eucalyptus plantations situated in marginal areas, poorly suitable for the cultivation of this tree species, were abandoned and the land was used for other purposes (M. Branco, unpublished observation).

In contrast to what is observed in forests, a large proportion of the arthropod pests attacking ornamental and urban trees in streets, parks and gardens in Europe are alien, partly because many tree species planted in urban areas are exotic. Common non-European pests of urban trees and shrubs include, among others, the lace bug *Corythucha ciliata*, the scales *Pulvinaria regalis* and *Pseudaulacaspis pentagona,* the American false webworm *Hyphantria cunea* and the arborvitae leaf miner *Argyresthia thuiella* (See factsheets 41, 45, 52, 64 and 77). The citrus longhorned beetle *Anoplophora chinensis* was recently introduced from Asia to Italy, where it is now established and spreading, despite an eradication programme. This polyphagous wood borer has already killed thousands of urban trees and shrubs in an area of nearly 200 km^2 (Tomiczek and Hoyer-Tomiczek 2007). Ornamental palms and their trade in the Mediterranean region are seriously threatened by several alien insects, in particular the Asian weevil *Rhynchophorus ferrugineus* and the South American moth *Paysandisia archon* (EPPO 2008a, 2008b).

Several of the most important tree pests in Europe invaded from other parts of the continent. The maritime pine bast scale, *Matsucoccus feytaudi*, an Iberian species, destroyed thousands of hectares of maritime pine forest in South-eastern France, Corsica and Italy, e.g. (Covassi and Binazzi 1992, Jactel et al. 1998, Riom 1994). Important ornamental tree pests in Central and Western Europe originate from the Balkans, such as the horse-chestnut leaf miner *Cameraria ohridella* (Tremblay 1984) and possibly the plane leaf miner, *Phyllonorycter platani* (Schönrogge and Crawley 2000). Many forest pests from continental Europe have invaded the British Isles, where they may cause severe damage to forest plantations, such as the spruce aphid *Elatobium abietinum* or the larger spruce bark beetle *Dendroctonus micans* (Day and Leather 1997).

Tree pests may have a direct economic effect through decrease of timber value, wood increment loss and tree mortality, treatment costs and costs related to early harvesting and replanting. There are few examples where the costs of alien forest pests have been calculated precisely in Europe. In the British Isles, the estimated cost to losses in forestry products due to alien arthropods is about $2 million per year, that is about 2% of the cost of alien arthropods in the agricultural sector (Pimentel 2002). These numbers may suggest that the direct economic impacts on forest products are much lower than on agricultural crops. The difference might partly be explained by the fact that trees may often sustain pest attacks without substantial growth loss and without tree mortality (Speight and Wainhouse 1989). Furthermore, dead trees may still have economic value as salvage. Still, it should be considered that forests account for only 11% of land cover in the British Isles (Forestry Commission 2006). In other European countries where the percentage of forest land cover is higher (e.g. 72% in Finland), the relative direct economic impact of alien forest pests will be much higher.

Higher impact values are obtained when control costs are included. For example, Reinhardt et al. (Reinhardt et al. 2003) estimated that the control of the horse-chestnut leaf miner, *Cameraria ohridella,* in Germany would cost 10.02 to 33.8 millions € per year and the replacement costs for all horse-chestnut trees would be as high as 10.7 billion €. The eradication and control costs against *A. chinensis* in Northern Italy amounted to 900,000 € in 2005/2006, but are supposed to reach 10 million € in the period 2008–2010 (Ciampitti 2009). Furthermore, forest ecosystems provide a variety of environmental services with high socio-economic value, such as water resources, soil protection, climate amenity, carbon sequestration and leisure. All these may be seriously hampered by tree defoliation and tree mortality caused by alien forest pests.

5.2.5. Arthropods affecting human and animal health

Human and animal health can be affected by various groups of alien arthropods, in particular detritivorous and hematophagous species. These generate economic costs related to control strategies, public health measures, health treatments, sick leave, educational programmes, etc. Some detritivores may affect human health by both food poisoning and disease transmission. For example, cockroaches, four of which are listed as alien in the DAISIE database, can carry microbes on their body surface and infest human and animal food. They can also provoke allergic reactions, including asthma (Brenner et al. 1987, Rivault et al. 1993).

Hematophagous arthropods, besides being a human nuisance through their biting behaviour, are also able to transmit diseases or to cause allergies and dermatitis to human or domestic animals (Lounibos 2002). Seven alien mosquitoes (Diptera: Culicidae) are found in Europe. The Asian tiger mosquito, *Aedes albopictus*, and the Asian rock pool mosquito, *Aedes japonicus*, have already invaded several European countries. They both are natural vector of various viruses and filaria for humans and domestic animals (Mitchell 1995, Schaffner et al. 2009). In summer 2007, in Italy, for the first time in Europe *A. albopictus* was found to be the vector of an infectious disease, the Chikungunya virus (Enserink 2007). Tropical and sub-tropical mosquito species are often accidentally introduced in Europe and, with global warming, there is a risk that more mosquito species and their associated diseases could become established, particularly in southern Europe.

The DAISIE database also mentions six fleas (Syphonaptera), 27 sucking louses (Phthiraptera) and 20 mites that are also able to transmit diseases or to cause allergies and dermatitis to human and animals (Roques et al. 2009). Worth mentioning are the rat flea, *Nosopsyllus fasciatus*, which is the primary vector for bubonic plague and murine typhus (Beaucornu and Launay 1990) and alien ticks of the genus *Hyalomma* that represent emerging risks for humans and animals in Europe by transmitting tick-borne rickettsial diseases (Parola 2004) (see chapter 7.2.). Finally, although the vast majority of the 48 alien Araneae in Europe are of no medical concern, several species of importance to human health are increasingly intercepted at entry ports, and a few are reported as being established, such as two *Loxosceles* spp. from America and a black widow, *Latrodectus hasselti*, from Australia (Kobelt and Nentwig 2008).

5.2.6. Arthropods with a positive economic impact

Although alien arthropods are mostly associated with negative effects, some alien species may generate substantial economic benefits. For example, many predators and parasitoids introduced as biological control agents to control alien pests have a positive economic impact. The update of the DAISIE database presented in this book lists 217 non-European arthropods acting as biocontrol agents of plant pests, or pests of stored products. Parasitoids include mostly chalcidoid wasps, in particular Aphelinidae (63 spp.) and Encyrtidae (55 spp.) whereas the most numerous introduced predators are Coccinellidae (12 spp.). Most of these species were intentionally introduced to control alien plant pests in outdoor crops or used as augmentative biological control agents in greenhouses. In Europe, the majority of the vegetable greenhouse area is under biological control or IPM (van Lenteren 2007), using a large variety of predators and parasitoids (van Lenteren et al. 1997). Various cost-benefit analyses have shown that, in greenhouses, biological control is the most cost-effective method (van Lenteren 2007). Many natural enemies established in the wild in Europe have a substantial impact on plant pests, such as the aphelinid *Aphelinus mali*, parasitoid of the woolly aphid *Eriosoma lanigerum*, and the coccinellid *Rodolia cardinalis*, predator of the cottony cushion scale *Icerya purchasi* (Greathead 1976). Some species released locally have been to spread quickly and rapidly become established in the wild. For example, the Australian parasitoid wasp, *Psyllaephagus pilosus*, which was released locally in southern France in 1997 to control the eucalyptus psyllid *Ctenarytaina eucalypti*, by 1998 had become established and spread westwards by more than 85 km (Malausa 1998). Interestingly, some of the most efficient natural enemies in Europe were introduced unintentionally, such as *Avetianella longoi*, an egg parasitoid of the eucalyptus woodborer *Phoracantha semipunctata* in Italy and Portugal (Farrall et al. 1992, Siscaro 1992), and *Closterocerus chamaeleon*, an Australian parasitoid of the eucalyptus gall wasp *Ophelimus maskelli* found in Portugal in 2007 (Branco et al. 2009).

Pollinators are other insects whose introductions are often considered beneficial. Species and sub-species of honeybee and bumblebee have been introduced into many parts of the world, including Europe, to improve pollination of cultivated plants, either in outdoor crops or in greenhouses (Ings et al. 2005a, 2005b, Moritz et al. 2005). However, the introduction of exotic pollinators and biological control agents may also have negative effects on the environment (see section 5.3 below).

5.3. Environmental impact

Alien arthropods can affect native biodiversity and ecosystem services and processes through various mechanisms (Kenis et al. 2009). Herbivores feeding on native plants can have a direct effect on host plant populations. Similarly, predators, parasites and parasitoids may directly affect their indigenous prey or host. Alien species may hybridize with native species, causing disturbances in native genetic resources. They can also affect the native flora and fauna and ecosystems indirectly, through cascading effects, or by carrying diseases, competing for food or space or sharing natural enemies with native species. However, these ecological impacts, their strength and the mechanisms underlying these impacts are poorly studied. Their interaction with the native fauna and flora has been rarely investigated, particularly if their habitat is of little economic concern. Based on the DAISIE database, Vilà et al. (2010) estimated that the percentage of alien terrestrial invertebrates having an ecological impact in Europe was 13.8%. However, in most cases, the notification of environmental impact was based on the fact that an alien arthropod may feed on a native plant or animal species and not on scientific evidence that populations or communities of native species are affected, or ecosystem processes are disturbed. In their extensive literature survey on the ecological effects of alien insects, Kenis et al. (2009) identified 72 alien insects worldwide for which an ecological impact had been investigated, and evidence for impact in the field was found for 54 of them. Among these, only a handful of cases came from Europe and, until now, none of them has had a tremendous impact on the environment, in contrast to what is observed in other continents. Table 1 shows the species for which an ecological effect on native biodiversity or ecosystems has been observed or investigated in Europe, and a selection of species for which an effect is suspected but for which scientific evidence is still lacking.

5.3.1. Impact by herbivores

In most continents, herbivores account for the largest number of alien insects of ecological concern. For example, several forest pests of Eurasian origin cause dramatic and irreversible effects on various forest ecosystems in North America (Kenis et al. 2009). In Europe, despite the fact that phytophagous insects largely dominate the alien fauna, hardly any are known to have an ecological impact on native biodiversity and ecosystems. A potential exception is the introduction of a butterfly, the small white, *Pieris rapae*, in Madeira, which coincided with the extinction of a congeneric species, the Madeiran large white, *P. brassicae wollastoni* (Wakeham-Dawson et al. 2002). The mechanisms involved in this extinction are unclear. Gardiner (2003) suggests that the introduction of *P. rapae* brought a different strain of the granulosis virus for which the native butterfly had no resistance, although loss of habitat, pollution from agricultural fertilisers and an exotic parasitoid are also blamed. Another study worth mentioning is that of Schönrogge and Crawley (2000), who investigated the impact of the invasion, in UK, of cynipid gall wasps of the genus *Andricus* on native gall wasps through the sharing of parasitoids and inquilines. They did not find evidence that the alien species had a long term effect on populations and communities of native species. Péré et al. (2010) observed that horse-chestnut trees *Aesculus hippocastanum* infested by the invasive leaf miner *Cameraria ohridella* had a negative effect on neighbouring populations and communities of native leaf miners. Although they suspected that the effect is due to shared natural enemies, further studies did not confirm this hypothesis (Péré and Kenis, unpubl. data).

Since recently, however, introductions of phytophagous insects in Europe are causing increasing concern for their current or potential impact on the native fauna or flora. The two most serious alien palm pests in Europe, *Rhynchophorus ferrugineus* and *Paysandisia archon*, are not only a problem for the trade of ornamental plants. They are also able to develop on, and kill three endemic palm species, *Phoenix theophrasti* in Crete and *P. canariensis* in the Canary Islands, in the case of both insects, *and Chamaerops humilis* in the western Mediterranean region in the case of *P. archon* (EPPO 2008a, 2008b). The Geranium bronze, *Cacyreus marshalli* is a South African lycaenid butterfly introduced into southern Europe, where is has developed as a serious pest of cultivated *Pelargonium* spp. Laboratory tests in Italy showed that it can also develop and kill native *Geranium* spp. (Quacchia et al. 2008) but further studies are needed to assess better the risk and impact on the wild flora and on native *Geranium*-consuming lycaenids.

The citrus longhorned beetle *Anoplophora chinensis* is presently still restricted to urban areas in Northern Italy, but it is expected to invade forests, where it could kill a large number of tree and shrub species and modify natural ecosystems. The chestnut gall wasp, *Dryocosmus kuriphilus*, a Chinese species damaging chestnut in Japan and North America has been recently found in Italy and is rapidly spreading to neighbouring countries, representing a serious threat for the European chestnut, a keystone species in some European forest ecosystems (Quacchia et al. 2008). Other alien phytophagous insects for which the ecological impact should be investigated include, among others: the western conifer seed bug, *Leptoglossus occidentalis*, which may affect the natural regeneration of conifers (Rabitsch and Heiss 2005); several seed chalcids of the genus *Megastigmus* that are suspected of displacing native congeneric species (Auger-Rozenberg and Roques 2008, Fabre et al. 2004); and *Metcalfa pruinosa*, a planthopper that massively attacks hundreds of different plant species in Southern Europe (Girolami et al. 1996).

However, the alien insect that represents the most serious threat to European biodiversity and ecosystems may well be the emerald ash borer, *Agrilus planipennis*, an Asian wood borer that was detected in North America in 2002. In a few years, it has already killed over 15 million ash trees, *Fraxinus* spp. (Poland and McCullough 2006). The beetle has recently been detected in the region of Moscow, where it has started to cause similar damage (Baranchikov et al. 2008). Considering its dispersal capacities, there is no doubt that *A. planipennis* will quickly invade the rest of Europe and poses a serious threat to the three European ash species which are valuable components of various European forest ecosystems.

5.3.2. Impact by ants

The alien arthropod which has been most studied for its ecological impact in Europe is undoubtedly the Argentine ant, *Linepithema humile*, a South American ant species that has invaded most continents, becoming one of the most damaging invasive insects on earth (Holway et al. 2002). In Europe, it has been reported in several countries, and has established large wild populations in Spain, Portugal, southern France and Italy. In Spain and Portugal, *L. humilis* was observed to displace the native ants including myrmecochorous ants, which had a negative effect on seed dispersal of native plants (Carpintero et al. 2005, Gómez and Oliveras 2003, Gómez et al. 2003, Way et al. 1997). Blancafort and Gómez (2005) noted that the invasion of *L. humile* reduces fruit-set and seed set of the native plant *Euphorbia characias*. In Madeira, however, it seems that *L. humile* and another invasive ant, *Pheidole megacephala* have little impact, even after 150 or more years of residence, and are dominated by the better adapted native ant, *Lasius grandis* (Wetterer et al. 2006). Way et al. (1997) noted that the displacement of native ants in Portugal was most noticeable on disturbed habitats. Also, *L. humile* preys on and reduces populations of serious tree pests such as the pine processionnary moth, *Thaumetopoea pityocampa,* and the eucalyptus wood borer (Way et al. 1992, 1999).

Lasius neglectus is another invasive ant in Europe, originating from Asia Minor. It is found in several European countries, but mainly in human-modified habitats, from strictly urban sites to gardens and urban woods. Nevertheless, it can be very aggressive against native ants and some populations in Spain have displaced other surface-foraging ants as well as other invertebrates, such as Lepidoptera (Espadaler and Bernal 2008). *Lasius neglectus* also tends arboreal aphids that may have a detrimental impact on trees. In England, Oliver et al. (2008) conducted laboratory studies on competitive interactions between native ants and *Technomyrmex albipes*, another alien ant that is presently restricted to protected habitats but may become invasive outdoors with future climate warming.

5.3.3. Impact by other predators and parasitoids

Biological control agents are usually considered as beneficial because they reduce the impact of pests and the use of pesticides. In some cases, however, they may become pests themselves and threaten non-target species or other beneficial organisms. The best known case in Europe is the harlequin ladybird, *Harmonia axyridis*, an Asian species used in biological control programmes against aphids on greenhouse and field crops since the 1980s. The first feral populations in Europe were found in Germany in 1999 and, since then, it has spread to at least 15 countries (Brown et al. 2008). In North America, where it was released earlier, it is known to displace native ladybirds through intra-guild predation and competition for food (Koch and Galvan 2008), and it is feared that the same effects will be observed on European ladybird species. Laboratory tests have already shown that European species are vulnerable to predation by *H. axyridis* (Burgio et al. 2002, Ware and Majerus 2008, Ware et al. 2008), but evidence for displacement in the field needs to be further studied (Adriaens et al. 2008).

Two parasitoids released to control plant pests in Europe are known to have affected populations of native parasitoids. The North American aphid parasitoid *Lysip-*

hlebus testaceipes, introduced in Mediterranean countries to control *Aphis spiraecola*, may have displaced two congeneric parasitoids, *L. fabarum* and *L. confusus* (Tremblay 1984). Similarly, the introduction of the South American *Cales noacki* in Italy to control the whitefly *Aleurothrixus floccosus*, has resulted in the displacement of the indigenous parasitoid *Encarsia margaritiventris*, parasitoid of the viburnum whitefly *Aleurotuba jelineki* (Viggiani 1994). However, in a recent paper, Viggiani (2008) stated that, in the two cases, the effects on the native parasitoids were largely local, that none of the affected native parasitoids is now endangered and that this displacement had no effect on pest populations.

Alien mosquitoes are not only a threat for human or animal health. They may also affect native mosquito species through competition (Juliano and Lounibos 2005). Following the invasion of the tiger mosquito, *Aedes albopictus* in Italy, Carrieri et al. (2003) carried out laboratory experiments to investigate potential competitive interactions with the native *Culex pipiens*. They found that *A. albopictus* was competitively superior in resource competition but, to date, the displacement of native mosquitoes has not been demonstrated in the field.

5.3.4. Impact by pollinators and impact on pollination

In Europe, as in other continents, insect pollinators, particularly bees, are declining, which may have dramatic consequences for the functioning of natural ecosystems and agriculture (Biesmeijer et al. 2006). Although the exact mechanisms leading to bees' decline is a matter of debate, there is no doubt that the accidental introduction of natural enemies has played a significant role. In particular, the parasitic mite, *Varroa destructor*, which originates from the Far East and was accidentally introduced into most continents since the 1950s, has largely contributed to the decline of cultivated honeybee, partly because of its association with viruses (Sammataro et al. 2000). This has surely had an indirect ecological effect on plant pollination, although this effect is difficult to quantify. In other parts of the world, it has been shown that *V. destructor* also has a serious impact on feral honeybee populations (Kraus and Page 1995), but such studies are still lacking in Europe. Honeybees and wild bees may soon be threatened by a new invader, the Asian hornet, *Vespa velutina* (see factsheet 64). This species was introduced in south-western France some years ago, probably in pieces of pottery imported from China (Villemant et al. 2006). It is known as an important predator of bees in Asia, and it has already been reported preying on domestic honeybees in France. In addition, it may displace the European hornet, *Vespa crabro*. The current and potential impact of this new alien species should be assessed for the whole of Europe and management measures should be developed.

The release in western and Northern Europe of two subspecies of the honeybee *Apis mellifera* originating from southern and eastern Europe, *A. m. ligustica* and *A. m. carnica*, has caused large-scale gene flow and introgression between these sub-species and the native black honeybee, *A. m. mellifera* (De La Rùa et al. 2002, Jensen et al. 2005, Moritz et al. 2005). In the Canary Islands, Dupont et al. (2003) showed that the introduced honeybees depleted nectar of a native plant, which reduced visitation by native pollinators and may have consequences on pollination. The bumblebee, *Bombus terrestris*, another important pollinator in Europe, is threatened by the importation of sub-species from the Middle East (*B. t. dalmatinus*) and Sardinia (*B. t. sassaricus*) introduced in Europe as pollinators of greenhouse crops. Commercial subspecies may hybridize with native ones and even displace them in the wild (Ings et al. 2005a, 2005b, 2006).

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5.5. References

Adriaens T, San Martin y Gomez G, Maes D (2008) Invasion history, habitat preferences and phenology of the invasive ladybird Harmonia axyridis in Belgium. *BioControl* 53: 69–88.

Auger-Rozenberg MA, Roques A (2008) Share the resources or displace the natives: different strategies in invasive *Megastigmus* seed insects. In: Proceedings of the 23rd International Congress of Entomology, Durban (South Africa), July 2008.

Baranchikov Y, Mozolevskaya E, Yurchenko G, Kenis M (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. *Bulletin OEPP/EPPO Bulletin* 38: 233–238.

Baufeld P, Enzian S (2005) Maize growing, maize high-risk areas and potential yield losses due to Western Corn Rootworm (*Diabrotica virgifera virgifera* LeConte) damage in selected European countries. In: Vidal S, Kuhlmann U, Edwards CR (Eds) *Western Corn Rootworm: Ecology and Management*. Wallingford, UK: CABI Publishing, 285–302.

Beaucornu JC, Launay H (1990) *Les puces de France et du Bassin Méditerranéen Occidental. Faune de France 76*. Paris : Fédération Française des Sociétés de Sciences Naturelles. 548 pp.

Biesmeijer JC, Roberts SPM, Reemer M, Ohlemuller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J, Kunin WE (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351–354.

Binimelis R, Born W, Monterroso I, Rodrígez-Labajos B (2007) Socio-economic impact and assessment of biological invasions. In: Nentwig W (Ed) *Biological Invasions*. Berlin: Spinger-Verlag.

Blancafort X, Gómez C (2005) Consequences of the Argentine ant, *Linepithema humile* (Mayr), invasion on pollination of *Euphorbia characias* (L.) (Euphorbiaceae). *Acta Oecologica* 28: 49–55.

Born W, Rauschmayer F, Bräuer I (2005) Economic evaluation of biological invasions -a survey. *Ecological Economics* 55: 321– 336.

Branco M, Boavida C, Durand N, Franco JC, Mendel Z (2009) Presence of the Eucalyptus gall wasp, *Ophelimus maskelli* (Ashmead) and its parasitoid *Closterocerus chamaeleon* Girault, in Portugal: first record, geographic distribution and host preference. *Phytoparasitica* 37: 51–54.

Brenner RJ, Koehler P, Patterson RS (1987) Health Implications of Cockroach Infestations. *Infections in Medicine* 4: 349–355.

Brødsgaard HF, Albajes R (1999) Insect and mite pests. In: Albajes R, Lodovica Gullino M, van Lenteren JC, Elad Y (Eds) Integrated Pest and Disease Management in Greenhouse Crops. Amsterdam: Kluwer Academic Publishers, 48–60.

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, Hägg T, Kenis M, Klausnitzer BEM, Kovar I, Loomans A, Majerus MEN, Nedved O, Pedersen J, Rabitsch W, Roy HE, Ternois V, Zakharov I, Roy DB (2008) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *BioControl* 53: 5–21.

Burgio G, Santi F, Maini S (2002) On intra-guild predation and cannibalism in *Harmonia axyridis* (Pallas) and *Adalia bipunctata* L. (Coleoptera: Coccinellidae). *Biological Control* 24: 110–116.

CABI (2007) *Crop Protection Compendium*. Wallingford, UK: CAB International. CD-ROM.

Carpintero S, Reyes-López J, Arias de Reyna L (2005) Impact of Argentine ants (*Linepithema humile*) on an arboreal ant community in Doñana National Park, Spain. *Biological Conservation* 14: 151–163.

Carrieri M, Bacchi M, Bellini R, Maini S (2003) On the competition occurring between *Aedes albopictus* and *Culex pipiens* (Diptera: Culicidae) in Italy. *Environmental Entomology* 32: 1313–1321.

Ciampitti M (2009) Case study: *Anoplophora chinensis* and *A. glabripennis*. Oral presentation at the EPPO Workshop on eradication, containment and contingency planning. Nova Gorica, Slovenia, 10–12.02.2009.

Covassi M, Binazzi A (1992) Primi focolai di *Matsucoccus feytaudi* Duc. nella Liguria orientale (Homoptera: Margarodidae). *Redia* 75: 453–466.

Day KR, Leather SR (1997) Threats to forestry by insect pests in Europe. In: Watt, AD, Stork NE, Hunter MD (Eds) *Forests and Insects.* London: Chapman & Hall, 177–205.

De La Rùa P, Serrano J, Galian J (2002) Biodiversity of Apis mellifera populations from Tenerife (Canary Islands) and hybridisation with East European races. *Biological Conservation* 11: 59–67.

Dupont YL, Hanse DM, Valido A, Olesen JM (2003) Impact of introduced honeybees on native pollination interactions of the endemic *Echium wildpretii* (Boraginaceae) on Tenerife, Canary Islands. *Biological Conservation* 118: 301–311.

ECPA (2007) European Crop Protection Association. http://www.ecpa.be [accessed 28.05.2009].

Enkerlin W, Mumford J (1997) Economic evaluation of three alternative methods for control of the Mediterranean fruit fly (Diptera: Tephritidae) in Israel, Palestinian Territories, and Jordan. *Journal of Economic Entomology* 90: 1066–1072.

Enserink M (2007) Tropical disease follows mosquitoes to Europe. *Science* 317: 1485.

EPPO (2008a) Datasheets on quarantine pests. *Rhynchophorus ferrugineus*. *Bulletin OEPP/EPPO* 38, 55–59.

EPPO (2008b) Datasheets on quarantine pests. *Paysandisia archon*. *Bulletin OEPP/EPPO* 38, 163–166.

Espadaler X, Bernal V (2008) *Lasius neglectus*. http://www.creaf.uab.es/xeg/lasius/index.htm

Fabre JP, Auger-Rozenberg MA, Chalon A, Boivin S, Roques A (2004) Competition between exotic and native insects for seed resources in trees of a Mediterranean forest ecosystem. *Biological Invasions* 6: 11–22.

Farrall MH, Paiva MR, Albino P (1992) Registo de uma nova espécie do género *Avetianella* (Hymenoptera, Encyrtidae) parasitóide oófago da broca do eucalipto *Phoracantha semipunctata* (Fab.). *Actas do Congresso Iberica de Entomologia* 5: 475–480.

Forestry Commission (2006) Forestry Statistics 2005. Available at [http://www.forestry.gov.uk/website/foreststats.nsf/byunique/woodland.html#one]

Gardiner BOC (2003) The possible cause of extinction of *Pieris brassicae wollastoni* Butler (Lepidoptera: Pieridae). *Entomologist's Gazette* 54: 267–268

Girolami V, Conte L, Camporese P, Benuzzi M, Martir GR, Dradi D (1996) Possibilita di controllo biologico della *Metcalfa pruinosa*. *Informatore Agrario*, 52: 25.

Gómez C, Oliveras J (2003) Can the Argentine ant (*Linepithema humile* Mayr) replace native ants in myrmecochory? *Acta Oecologica* 24: 47–53.

Gómez C, Pons P, Bas JM (2003) Effects of the Argentine ant *Linepithema humile* on seed dispersal and seedling emergence of *Rhamnus alaternus*. *Ecography* 26: 532–538.

Gonzalez Tirado L (1986) *Phoracantha semipunctata* dans le Sud-Ouest espagnol: lutte et dégâts. *Bulletin OEPP/EPPO* 16: 289–292.

Greathead DJ (Ed) (1976) *A review of biological control in western and southern Europe* . Technical Communication No. 7. Farnham Royal, UK: Commonwealth Institute of Biological Control CAB. 182 pp.

Heikkilä J, Peltola J (2006) Phytosanitary measures under uncertainty: a cost benefit analysis of the Colorado potato beetle in Finland. In: AGJM Oude Lansink (Ed) New *Approaches to the Economics of Plant Health*. Heidelberg, Germany: Springer-Verlag, 147–161.

Holway DA, Lach L, Suarez A, Tsutsui N, Case TJ (2002) The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics* 33: 181–233.

Hulme PE, Nentwig W, Pyšek P, Vilà M (Eds) (2009) DAISIE, *The Handbook of Alien Species in Europe*. Dordrecht: Springer. 399 pp.

Ings TC, Raine NE, Chittka L (2005a) Mating preference of commercially imported bumblebees (Bombus terrestris) in Britain (Hymenoptera: Apidae). *Entomologia Generalis* 28: 233–238.

Ings TC, Schikora J, Chittka L (2005b) Bumblebees, humble pollinators or assiduous invaders? A population comparison of foraging performance in Bombus terrestris. *Oecologia*, 144: 508–516.

Ings TC, Ward NL, Chittka L (2006) Can commercially imported bumble bees out-compete their native conspecifics? *Journal of Applied Ecology* 43: 940–948.

Jactel H, Menassieu P, Ceria A, Burban C, Regad J, Normand S, Carcreff E (1998) Une pullulation de la cochenille *Matsucoccus feytaudi* provoque un début de dépérissement du pin maritime en Corse. *Revue Forestière Française* 50: 33–45.

Jensen AB, Palmer KA, Boomsma JJ, Pedersen BV (2005) Varying degrees of *Apis mellifera ligustica* introgression in protected populations of the black honeybee, *Apis mellifera mellifera*, in northwest Europe. *Molecular Ecology* 14: 93–106.

Juliano SA, Lounibos LP (2005) Ecology of invasive mosquitoes: Effects on resident species and on human health. *Ecology Letters* 8: 558–574.

Kenis M, Rabitsch W, Auger-Rozenberg M-A, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Kenis M, Auger-Rozenberg M-A, Roques A, Timms L, Péré C, Cock MJW, Settele J, Augustin S, Lopez-Vaamonde C (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Kobelt M, Nentwig W (2008) Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Koch RL, Galvan TL (2008) Bad side of a good beetle: the North American experience with *Harmonia axyridis*. *BioControl* 53: 23–35.

Kraus B, Page RE Jr. (1995) Effect of *Varroa jacobsonia* (Mesostigmata: Varroidae) on feral *Apis mellifera* (Hymenoptera: Apidae) in California. *Environmental Entomology* 24: 1473–1480.

Lounibos LP (2002) Invasions by insect vectors of human disease. *Annual Review of Entomology* 47: 233–66.

MacLeod A (2006) The benefits and costs of specific phytosanitary campaigns in the UK. Examples that illustrate how science and economics support policy decision making. In: AGJM Oude Lansink (Ed) New *Approaches to the Economics of Plant Health*. Heidelberg, Germany: Springer-Verlag, 163–177.

MacLeod A, Head J, Gaunt A (2004). An assessment of the potential economic impact of *Thrips palmi* on horticulture in England and the significance of a successful eradication campaign. *Crop Protection*b23: 601–610.

Malausa JC (1998) Des insectes au secours des eucalyptus. *Biofutur* 176: 34–37.

Mansilla P, Pérez R (1996) El defoliador del eucalipto *Gonipterus scutellatus*. *Phytoma España* 81: 36–42.

Mitchell CJ (1995) Geographic spread of *Aedes albopictus* and potential for involvement in arbovirus cycles in the Mediterranean basin. *Journal of Vector Ecology* 20: 44–58.

Moritz RFA, Härtel S, Neumann P (2005) Global invasions of the western honeybee (*Apis mellifera*) and the consequences for biodiversity. *Ecoscience* 12: 289–301.

Oliveira MRV, Henneberry TJ, Anderson P (2001) History, current status, and collaborative research projects for *Bemisia tabaci*. *Crop Protection*. 20: 709–723.

Oliver TH, Pittitt T, Leather SR, Cook JM (2008) Numerical abundance of invasive ants and monopolisation of exudate-producing resources – a chicken and egg situation. *Insect Conservation and Diversity* 1: 208–214.

Parola P (2004) Tick-borne rickettsial diseases: emerging risks in Europe. *Comparative Immunology, Microbiology and Infectious Diseases*. 27: 297–304

Péré C, Augustin S, Tomov R, Peng L-H, Turlings TCJ, Kenis M (2009a) Species richness and abundance of native leaf miners are affected by the presence of the invasive horse-chestnut leaf miner. *Biological Invasions*. Online first. Doi: 10.1007/s10530–009–9518–0.

Péré C, Augustin S, Turlings TCJ, Kenis M (2009b) The invasive alien leaf miner, *Cameraria ohridella* and the native maple, Acer pseudoplatanus: a fatal attraction? *Agricultural and Forest Entomology*. In press.

Pimentel D (2002) Non-native invasive species of arthropods and plant pathogens in the British Isles. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 151–155.

Pimentel D (2007) Area-Wide Pest Management: Environmental, Economic, and Food Issues. In: Vreysen MJB, Robinson AS, Hendrichs J (Eds) *Area-Wide Control of Insect Pests:* from research to field implementation. Dordrecht, The Netherlands: Springer, 35–47.

Pimentel D, Lach L, Zuniga R, Morrison D (2002a) Environmental and economic costs associated with non-indigenous species in the United States. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 285–306.

Pimentel D, McNair S, Janecka J, Wightman J, Simmonds C, O'Connell C, Wong E, Russel L, Zern J, Aquino T, Tsomondo T (2002b) Economic and environmental threats of alien plant, animal and microbe invasions. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 307–330.

Poland TM, McCullough DG (2006) Emerald ash borer: invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* 104: 118–124.

Quacchia A, Ferracini C, Bonelli S, Balletto E, Alma A (2008a) Can the Geranium Bronze, *Cacyreus marshalli*, become a threat for European biodiversity? *Biodiversity and Conservation* 17: 1429–1437.

Quacchia A, Moriya S, Bosio G, Scapio I, Alma A (2008b) Rearing, release and settlement prospect in Italy of Torymus sinensis, the biological control agent of the chestnut gall wasp. *BioControl* 53: 829–839.

Rabitsch W, Heiss E (2005) *Leptoglossus occidentalis* Heidemann, 1910, eine amerikanische Adventivart auch in Österreich aufgefunden (Heteroptera, Coreidae). *Berichte des naturwissenschaftlichmedizinischen Verein Innsbruck* 92: 131–135.

Rautapaa J (1984) Costs and benefits of quarantine measures against *Liriomyza trifolii* in Finland. *EPPO Bulletin*: 14: 343–347.

Rees D (2004) *Insects of Stored Products*. Collingwood, VIC, Australia: CSIRO Publishing, Australia.

Reinhardt F, Herle M, Bastiansen F, Streit B (2003) Economic impact of the spread of alien species in Germany. Berlin, Germany: Federal Environmental Agency (Umweltbundesamt). 229 pp.

Rivault C, Cloarec A, Le Guyader A (1993) Bacterial load of cockroaches in relation to urban environment. *Epidemiology and Infection* 110: 317–325.

Riom J (1994) Le dépérissement du pin maritime dans le Sud-Est de la France au cours des années 1960–1970: Le rôle de la cochenille *Matsucoccus feytaudi* Duc. (Coccoidea, Margarodidae). *Revue Forestière Française* 66, 437–445.

Roosjen M, Buurma J, Barwegen J (1998) Verbetering schade-inschattingsmodel quarantaineorganismen glastuinbouw. *Verslagen en Mededelingen, Plantenziektenkundige Dienst, Wageningen* 197: 1–24.

Roques A (2010) Alien forest insects in a globalized, warmer world: Impacts of global change (trade, tourism, climate) on forest biosecurity. *New Zealand Journal of Forestry Science* (in press).

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: Hulme PE, Nentwig W, Pyšek P, Vilà M (Eds) *DAISIE, The Handbook of Alien Species in Europe*. Heidelberg, Germany: Springer, 63–79.

Sammataro D, Gerson U, Needham G (2000) Parasitic mites of honey bees: life history, implications, and impact. *Annual Review of Entomology* 45: 519–548.

Schaffner F, Kaufmann C, Hegglin D, Mathis A (2009) The invasive mosquito *Aedes japonicus* in Central Europe. *Medical and Veterinary Entomology* 23: 448–451.

Schönrogge K, Crawley MJ (2000) Quantitative webs as a means of assessing the impact of alien insects. *Journal of Animal Ecology* 69: 841–868.

Šefrová, H (2001) *Phyllonorycter platani* (Staudinger) a review of its dispersal history in Europe (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 49: 71–75.

Siscaro G (1992) *Avetianella longoi* sp. n. (Hymenoptera, Encyrtidae) egg parasitoid of *Phoracantha semipunctata* F. (Coleoptera, Cerambycidae). Bollettino di Zoologia agraria e di Bachicoltura 24: 208–211.

Sivcev I, Tomasev I (2002). Distribution of *Diabrotica virgifera virgifera* LeConte in Serbia in 1998. *Acta* Phytopathologica et Entomologica Hungarica 37: 145–153.

Speight MR, Wainhouse D (1989) *Ecology and Management of forest insects*. New York: Oxford University Press.

Tomiczek C, Hoyer-Tomiczek U (2007) Asian longhorned beetle (*Anoplophora glabripennis*) and citrus longhorned beetle (Anoplophora chinensis) in Europe - actual situation. *Forstschutz Aktuell* 38: 2–5.

Tremblay E (1984) The parasitoid complex (Hym.: Ichneumonoidea) of *Toxoptera aurantii* (Hom.: Aphidoidea) in the Mediterranean area. *Entomophaga* 29: 2003–2010.

Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkanic origin for the highly invasive Horse-Chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). *Molecular Ecology* 18: 3458–3470.

van Lenteren JC (2007) Biological control for insect pests in greenhouses: an unexpected success. In: Vincent C, Goettel MS, Lazarovits G (Eds) *Biological Control. A Global Perspective*. Wallingford, UK: CAB International, 105–117.

van Lenteren JC, Roskam MM, Timmer R (1997) Commercial mass production and pricing of organisms for biological control of pests in Europe. *Biological Control* 10: 143–149.

Viggiani G (1994) Recent cases of interspecific competition between parasitoids of the family Aphelinidae (Hymenoptera: Chalcidoidea). *Norwegian Journal of Agricultural Sciences Supplement* 16: 353–359.

Viggiani G (2008) Reflections and evidences on the present status of biological control of arthropod pests. Presentation at the International Congress of Entomology, 6–12 July 2008, Durban South Africa.

Vilà M, Basnou C, Pysek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE, DAISIE partners (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. *Frontiers in the Ecology and the Environment.* Online first. doi:10.1890/080083.

Villemant C, Haxaire J, Streito JC (2006) Premier bilan de l'invasion de *Vespa velutina* Lepeletier en France (Hymenoptera, Vespidae). *Bulletin de la Société entomologique de France* 111: 535–538.

Wakeham-Dawson A, Franquinho Aguiar AM, Martin G (2002) The distribution of endemic butterflies (Lepidoptera) on the island of Madeira, Portugal since 1850, with comments on their current conservation status. *Entomologist's Gazette* 53: 153–180.

Ware RL, Majerus MEN (2008) Intraguild predation of immature stages of British and Japanese coccinellids by the invasive ladybird *Harmonia axyridis*. *BioControl* 53: 169–188.

Ware RL, Evans N, Malpas L, Michie LJ, O'Farrell K, Majerus MEN (2008) Intraguild predation by the invasive ladybird *Harmonia axyridis*. British and Japanese coccinellid eggs. *Neobiota* 7: 263–275.

Way MJ, Cammell ME, Paiva MR (1992) Studies on egg predation by ants (Hymenoptera: Formicidade) especially on the eucalyptus borer *Phoracantha semipunctata* (Coleoptera: Cerambycidae) in Portugal. *Bulletin of Entomological Research* 82: 425–432.

Way MJ, Cammell ME, Paiva MR, Collingwood C (1997) Distribution and dynamics of the Argentine ant Linepithema (Iridomyrmex) humile (Mayr) in relation to vegetation, soil conditions, topography and native competitor ants in Portugal. *Insectes Sociaux* 44: 415–433.

Way MJ, Paiva MR, Cammell ME (1999) Natural biological control of the pine processionary moth Thaumetopoea pityocampa (Den. & Schiff.) by the Argentine ant Linepithema humile (Mayr) in Portugal. Agr Forest Entomol 1: 27–31.

Wetterer JK, Espadaler X, Wetterer AL, Aquin-Pombo D, Franquinho-Aguilar AM (2006) Long-term impact of exotic ants on the native ants of Madeira. Ecol Entomol 31: 358–368.

Williamson M (1996) Biological Invasions. Chapman and Hall, London, p. 244.

Table 5.1. Examples of alien species with current or potential environmental impact in Europe. **A** Species for which field studies have been published **B** Species for which only laboratory studies have been published **C** Species that may have an environmental impact now or in the near future and for which studies are needed. Details and references are found in the text.

	Impact observed	
A	In the field	In the lab
Andricus spp. (Hym.: Cynipidae)	No	
Apis mellifera L. subspecies *carnica*, *caucasica* and *ligustica* (Hym.: Apidae)	Yes	
Bombus terrestris (L.) subspecies *dalmatinus* and *sassaricus* (Hym.: Apidae)	Yes	
Cales noacki Howard (Hym.: Aphelinidae)	Yes	
Cameraria ohridella Deschka & Dimic (Lep.: Gracillariidae)	Yes	
Lasius neglectus Van Loon, Boomsma & Andrásfalvy (Hym.: Formicidae)	Yes	
Linepithema humile (Mayr) (Hym.: Formicidae)	Yes	
Lysephlebus testaceipes (Cresson) (Hym.: Braconidae)	Yes	
Megastigmus rafni Hoffmeyer (Hym. : Torymidae)	Yes	
Megastigmus schimitscheki Novitzky (Hym.: Torymidae)	Yes	
Pieris rapae (L.) (Lep.: Pieridae)	Unclear	
Pheidole megacephala (F.) Hym.: Formicidae)	No	
B		
Aedes albopictus (Skuse) (Dipt.: Culicidae)		Yes
Cacyreus marshalli Butler (Lep.: Lycaenidae)		Yes
Harmonia axyridis (Pallas) (Hym.: Coccinellidae)		Yes
Technomyrmex albipes Smith (Hym.: Formicidae)		Yes
C		
Agrilus planipennis Fairmaire (Col.: Buprestidae)		
Anoplophora chinensis (Forster) (Col. : Cerambycidae)		
Dryocosmus kuryphilus Yasumatsu (Hym.: Cynipidae)		
Leptoglossus occidentalis Heidemann (Hem.: Coreidae)		
Metcalfa pruinosa Say (Hem. : Flatidae)		
Paysandisia archon (Burmeister) (Lep.: Castniidae)		
Rhynchophorus ferrugineus (Olivier) (Col.: Curculionidae)		
Varroa destructor Anderson & Trueman (Acari: Parasitidae)		
Vespa velutina nigrothorax Lepeletier (Hym.: Vespidae)		

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RESEARCH ARTICLE

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Future trends
Chapter 6

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Introduction

The data supplied in the preceding chapters clearly confirm that the ever-increasing rate of arthropod invasions can be attributed to the upward trend in international freight transport, to passenger travel and, more generally, to globalization. The role that humans play in pest introductions as well as their likely dispersion is obvious and consequently there are strong geographic associations between higher numbers of alien pest occurrences and urban areas as already been noted by Colunga- Garcia et al. (2010) and Pyšek et al. (2010). Another important source of introduced arthropods comes from intentional releases, especially of alien hymenopterans, for the purpose of biological control programs. Invasive alien species threaten forests, agriculture, human and animal health. While economic losses attributed to exotic plant pests are poorly estimated in Europe (but see Vilá et al. 2009), they have been estimated at US $37.1 billion per year in U.S. agricultural and forest ecosystems (Pimentel et al. 2005). Invasive species can also cause irreversible changes to ecosystems, but there is no estimate of the full economic costs of their effects on ecosystems and on the human population that is dependent on them.

There is little chance that biological exchanges over borders may decrease in the next decades. Rather, the number of arthropod invasions will continue to grow, threatening economy and ecosystems globally. More and more people or agricultural commodities will cross borders, increasing the likelihood that arthropods will be translocated from one area of the world to another (Liebhold et al. 2006). In Europe, monitoring, detection of arthropod invasion mostly relies on poorly connected structures hosted by different countries, using non-interoperable tools that imply months if not years to detect the data for characterizing and managing new aliens. Such delays are unacceptable in cases where immediate action has to be taken. Globalization of biological exchanges should be met by globalization of the tools used to predict, detect and manage future bio-invasions.

Until now, no integrated biosecurity tool has been developed for arthropods (this is also true for all other bioinvaders). An ideal web-based integrated tool would encompass different interlinked modules to:

1. Identify the most likely future arthropod invaders
2. Provide generic and accurate identification tools
3. Compile biological information on these species
4. Predict where such aliens might potentially thrive, and their future distributions in a warmer climate or under
5. Estimate the full costs of the most likely alien arthropods
6. Finally, quantify and map risks associated with these non-indigenous species and prioritize them

Identify the most likely future arthropod invaders

Determining which species to target for development of detection tools, distributional area and risk estimation is not an easy task. However, it is increasingly important to identify potential invasive species prior to their introduction and establishment. This may help to reduce the likelihood of alien invasions and better define management scenarios. Only few studies have been published that help to select the most likely future arthropod invaders to Europe within the many thousands of potential bioinvader arthropods.

Worner and Gevrey (2006) recently developed an original and efficient method to identify potential invasive insects that should be subject to more detailed risk assessments. They based their study on 1) the assumptions that geographical areas with similar pest assemblages share similar biotic and abiotic conditions, 2) a comprehensive database of the global presence or absence of pests. They used artificial neural network analysis to propose a list of species that are ranked according to the risks they pose. It is important to develop further methods of this kind, to implement databases and make them easily accessible through web interfaces. The development of integrated European projects such as PRATIQUE (Enhancements of Pest Risk Analysis Techniques) is a step towards this goal (Baker et al. 2009).

The search for taxa that are particularly invasive worldwide may also benefit from phylogenetic or hierarchical clustering studies. Recent work on the hierarchical patterns in biological invasions has produced results that show both clustering as well as overdispersion of certain life-history traits that are associated with invasion success (e.g. reproductive traits) (Lambdon 2008, Procheş et al. 2008). In some cases, traits associated with invasiveness observed in a set of taxa tend to be more similar in closely related taxa, a phenomenon supposed to be linked to the conservation of ecological niches in closely related species. This observation provides promise that analysing these traits in a strict phylogenetic framework may help to predict better the most likely potential invasive species. However, few phylogenetic analyses of invasiveness have been proposed for arthropods. Such analyses may benefit from the development of DNA barcoding applied to multiple genes (see below) that could help in particular to reconstruct phylogenies within species complexes.

Another approach, for phytophagous invaders at least, could be to identify and establish 'sentinel' host plants in not yet invaded regions, to evaluate the impact of indigenous potential invaders in source regions should they become introduced as exotics at a later date (Britton et al. 2009). This is currently carried out in China for potential pests of European tree species (Roques et al. 2009; Roques 2010).

Provide generic and accurate identification tools

In the last few years, the application of molecular diagnostic methods have greatly accelerated. At the same time, DNA barcoding based on the mtDNA COI gene as well as nuclear markers, have shown great potential to improve the detection of invasive species. DNA barcoding has been used to detect pests efficiently (Armstrong 2010) and may also enable the flagging of invasive species trapped during biodiversity surveys (deWaard et al. 2009). Consequently, DNA barcoding many provide an efficient new tool in the biosurveillance armoury for detection of alien species. Next generation sequencing technologies (e.g. pyro and single-molecule sequencing) may further help to reduce costs and to increase both speed and quantity of molecular detection of arthropod species. In the near future, it is likely that most identifications of arthropods will proceed through comparison of multiple gene sequences to an online global library whose quality is vastly enhanced by taxonomic knowledge. Consequently, developing a worldwide DNA library of barcodes of the most likely invasive species, including all pests and their natural enemies that could be used in biological control project, is of strategic importance to enhance our ability to detect and manage invasive populations. Such a comprehensive database coupled to real time analysis of trapping may help to detect species even at low densities, long before they become established. Developing such an integrated detection toolkit may clearly improve both biosurveillance and biosecurity in the future.

Compile biological information on these species

Any introduced arthropod has an area of origin where it could already be a pest and where it may already have been studied and its biology described. Available lists of invasive species (NISIC, DAISIE, NOBANIS, etc) do not always provide an up-to-date compilation of all available biological information and so may be of limited use for improving future management or predicting spread. To infer better the potential distribution, costs and risks associated with the most likely arthropod invaders, we need to compile all available information on their biology and life-history traits, both in their native and, when possible, in their invaded ranges (Broennimann and Guisan 2008).

Predict where such aliens might potentially thrive

Predicting which arthropods can invade where is critical for their management, and ultimately in limiting the negative impacts of bioinvaders. Niche-based models are widely used to predict potential distributions of invasive insects, mites or other arthropods. These methods use observations either from the invaded or the native range of an invasive species to predict the potential range in the area of introduction. However, despite its increasing use, environmental niche modelling is based on fundamental assumptions that are easily violated and lead to incorrect prediction of the full extent of biological invasions. For example, the alien species may not occupy all suitable habitats when its ecological requirements have changed during the invasion process. Furthermore, predictions are sensitive not only to occurrence and environmental data, but also to the methods used to calibrate the models. These approaches have also been criticised for their lack of consideration of species interactions (natural enemies), dispersal, availability and synchrony with the host plant or host. However, unless we can accurately parameterize the relationship between a species and its environment, no single model predicting the invasive range is likely to represent reality. This task may prove to be not feasible for most arthropods, for which knowledge of their distribution and interactions is as yet fragmentary if not rudimentary. Consequently, multiple modelling methods are required to provide better prediction and error estimates for arthropod distributional areas, especially when based on poor observation datasets.

Moreover, identification of consensus areas of distributional estimate consistency using these different methods may help to produce more reliable estimates of species' potential distributions (Roura-Pascual et al. 2009). A recent study also showed that using predictions based on both abiotic variables (usually climate) and biotic ones (for insect or host assemblage) may be more accurate than predictions based on climatic factors alone (Watts and Worner 2008). Consequently, in an effort to improve the management of invasive arthropods to Europe, we need to 1) develop a comprehenive database of life-history traits and worldwide occurrences of invasive arthropods; 2) build or implement a system providing the most accurate projections based on this database; 3) develop free access tools that implement all these methods; 4) allocate research investment to such a task that will strongly improve both predictive methodology and knowledge of the most likely invasive arthropods and their natural enemies.

Estimate the full costs of the most likely alien arthropods

Until now few general models of the economic costs of biological invasion have been developed. The goal of such models is to develop effective management programs, that seek both to estimate current or future impacts of alien invasive species, and to prevent, control, or mitigate their biological invasion. Estimates of the full costs of biological invasions (i.e., beyond direct damages or control costs) are still rare, since the costs of such complex problems are hard to calculate. Vilá et al. (2009) provided a first continent-wide assessment of impacts on ecosystem services by all major alien taxa, including invertebrates, in terrestrial, freshwater, and marine environments. They tried to compare how alien species from the different taxonomic groups affect "supporting", "provisioning", "regulating", and "cultural" services and interfere with human well-being. However, many of these components are difficult if not impossible to quantify, such as the impacts of alien invasive species on biodiversity, ecosystem functions, human health and other indirect costs, for instance the impacts themselves of control measures. Furthermore, estimating the costs of an invasive arthropod that threatens biodiversity rather than agricultural production is particularly challenging. Precise economic costs associated with the most ecologically damaging alien species are simply not available. Consequently, we need to develop analysis of the ecological impact of introduced arthropods, especially those that are intentionally introduced for biological control purposes (Kenis et al. 2009). This is particularly important if we want in the near future to decrease our intake of pesticides and promote biological control.

Economic applications are also essential to provide more accurate and comprehensive assessments of the benefits and costs of control alternatives that can increase the effectiveness and efficiency of publicly funded programs. There is also a need for the development of better databases and modelling approaches to estimate better damages from invasive species and their control costs. Further research should also be conducted to narrow the uncertainty of the estimates. Work in these areas should help improve invasive species policy and achieve a more effective use of resources. Future cost estimates should be computed, within a real-time estimation procedure, using updated infestation measuresand regional input-output economic data.

Quantify and map risks associated with these non-indigenous species

In the case of invasive species, risk can be defined as the probability that an invader will become established in an area along with some evaluation of the economic consequences of this event. Traditionally, quantifying risks associated with arthropod invasive species require studies on 1) the process of introduction, dispersion and the pathways used; and 2) the economic consequences of spread in recently contaminated areas (Yemshanov et al. 2009). However - as emphasized above - biology, life history and full costs of most potential invasive arthropods are still poorly known and most risk assessment studies rely on expert judgment or rudimentary analytical approaches.

Here again the need of integrated tools is overwhelming to produce efficient risk assessment for policy-makers.

Toward a global european tool

Already 1590 alien arthropod species have been introduced and established in Europe and increased efforts are needed to minimize the risk of introductions and spread of additional species in the future.

Europe is poorly structured to detect rapidly, efficiently manage and control invasive arthropod species. In face of this global problem, European countries mostly have responded through nation-specific strategies and disconnected or weakly integrated projects. This disappointing situation must be changed. Faced with increasing economic pressure and despite already large grants in the past, the European Community has to invest more on invasive species prevention, detection and management.

One of the key elements is the need to establish a European early warning system and rapid response framework (Genovesi 2009). In the present situation where ornamental trade is a dominant pathway for invasion by phytophagous arthropods, a more thorough survey of parks, gardens and nurseries may function as such an early warning system. This could also be accompanied by the installation of more sophisticated quarantine and control measures at invasion 'hubs' for the ornamental plant trade (e.g. in the Netherlands) (Roques 2010).

While there is also a clear need for further research to understand better the ecological and genetic processes that facilitate the introduction and subsequent dispersion of exotic arthropods in agricultural and forest ecosystems (Facon et al. 2006), additional challenges include the improvement of Europe-wide biosurveillance and prediction tools. Clearly, the management of arthropod invasions will be enhanced by the integration and future improvement of already existing but widely dispersed tools. Researchers have to develop prototype Internet based systems to detect and manage better new arthropod invasions, and these tools should be reinforced through international collaborations. We are dealing with an outstanding global problem.

References

Armstrong K (2010) DNA barcoding: a new module in New Zealand's plant biosecurity diagnostic toolbox. *EPPO Bulletin* 40: 91–100.

Baker RHA, Battisti A, Bremmer J, Kenis M, Mumford J, Petter F, Schrader G, Bacher S, De Barro P, Hulme PE, Karadjova O, Lansink AO, Pruvost O, Pyšek P, Roques A, Baranchikov Y, Sun JH (2009) PRATIQUE: a research project to enhance pest risk analysis techniques in the European Union. *EPPO Bulletin* 39: 87–93.

Britton KO, White P, Kramer A, Hudler G (2009) Global Network of Sentinel Plantings: Recruiting Botanic Gardens and Arboreta to Stop the Spread of Invasive Species. In: *Abstracts* *of the IUFRO International Forest Biosecurity Conference*, Roturoa, New Zealand, 16–20 March 2009. *New Zealand Forest Research Institute Bulletin* 233: 104.

Broennimann O, Guisan A (2008) Predicting current and future biological invasions: both native and invaded ranges matter. *Biology Letters* 4: 585–589.

Colunga-Garcia M, Haack RA, Magarey RA, Margosian ML (2010) Modeling spatial establishment patterns of exotic forest insects in urban areas in relation to tree cover and propagule pressure. *Journal of Economic Entomology* 103: 108–118.

deWaard JR, Landry JF, Schmidt C, Derhousoff J, McLean JA et al. (2009) In the dark in a large urban park: DNA barcodes illuminate cryptic and introduced moth species. *Biodiversity and Conservation* 18: 3825–3839.

Facon B, Genton BJ, Shykoff J, Jarne P, Estoup A et al. (2006) A general eco-evolutionary framework for understanding bioinvasions. *Trends in Ecology and Evolution* 21: 130–135.

Genovesi P (2009) Toward a global biosecurity policy. In: *Abstracts of the International Conference of Biological Invasions* (*ICBI*), Fuzhou (Fujian), China, 2–6 November 2009: 9. http://invasivespecies.org.cn/uploadfile/20091207/20091207105632670.pdf.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Pere C et al. (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Lambdon PW (2008) Is invasiveness a legacy of evolution? Phylogenetic patterns in the alien flora of Mediterranean islands. *Journal of Ecology* 96: 46–57.

Liebhold AM, Work TT, McCullough DG, Cavey JF (2006) Airline baggage as a pathway for alien insect species invading the United States. *American Entomologist* 52: 48–54.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288.

Procheş S, Wilson JRU, Richardson DM, Rejmánek M (2008) Searching for phylogenetic pattern in biological invasions. *Global Ecology and Biogeography* 17: 5–10.

Roques A, Fan JT, Yart A, Sun JH (2009) Planting sentinel European trees in China, a tool for identifying potential insect and pathogen invaders. In: *Abstracts of the International Conference of Biological Invasions* (*ICBI*), Fuzhou (Fujian), China, 2–6 November 2009: 85. http://invasivespecies.org.cn/uploadfile/20091207/20091207105632670.pdf.

Roques A (2010) Alien forest insects in a warmer world and a globalized economy: Impacts of changes in trade, tourism and climate on forest biosecurity. *New Zealand Journal of Forestry*, suppl 40: 77–94.

Roura-Pascual N, Brotons L, Peterson AT, Thuiller W (2009) Consensual predictions of potential distributional areas for invasive species: a case study of Argentine ants in the Iberian Peninsula. *Biological Invasions* 11: 1017–1031.

Vilá M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE and Daisie Partners (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European cross-taxa assessment. *Frontiers in Ecology and the Environment* 8: 135–144.

Watts MJ, Worner SP (2008) Comparing ensemble and cascaded neural networks that combine biotic and abiotic variables to predict insect species distribution. *Ecological Informatics* 3: 354–366.

Worner SP, Gevrey M (2006) Modelling global insect pest species assemblages to determine risk of invasion. *Journal of Applied Ecology* 43: 858–867.

Yemshanov D, McKenney DW, de Groot P, Haugen D, Sidders D et al. (2009) A bioeconomic approach to assess the impact of an alien invasive insect on timber supply and harvesting: a case study with *Sirex noctilio* in eastern Canada. *Canadian Journal of Forest Research* 39: 154–168.

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Alien terrestrial crustaceans (Isopods and Amphipods) Chapter 7.1

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Abstract

A total of 17 terrestrial crustacean species aliens *to* Europe of which 13 isopods (woodlice) and 4 amphipods (lawn shrimps) have established on the continent. In addition, 21 species native to Europe were introduced in a European region to which they are not native. The establishment of alien crustacean species in Europe slowly increased during the 20th century without any marked changes during the recent decades. Almost all species alien *to* Europe originate from sub-tropical or tropical areas. Most of the initial introductions were recorded in greenhouses, botanical gardens and urban parks, probably associated with passive transport of soil, plants or compost. Alien woodlice are still confined to urban habitats. Natural habitats have only been colonized by three amphipod species in the family Talitridae.

Keywords

Woodlice, lawnshrimps, Europe, alien

7.1.1. Introduction

The orders in the arthropod subphylum Crustacea are mainly composed of aquatic-living species, at least during part of their life-cycle. Most alien terrestrial crustaceans belong to the order Isopoda, suborder Oniscidea, commonly named woodlice. But several species recorded in Europe belong to the order Amphipoda, and are commonly known as “lawn shrimps” or “landhoppers”.

In 2004, the total number of valid Isopod species worldwide was 3637 (Schmalfuss 2003). Woodlice are adapted to various terrestrial environments from sea shores to deserts and have established on all continents. As decomposers of organic plant material, isopods play an important role in ecosystems (Holthuis et al. 1987, Zimmer 2002). Most European species prefer humid and moist micro-habitats (Vandel 1960) like soil, leaf litter, mosses and decaying wood. Several species are known for their myrmecophylic nature.

Amphipods are generally marine or limnicolous, and only a few species can live permanently on land (mainly in the family Talitridae). Some live near the sea, on beaches where they hide under logs and dead algae and vegetation. The true terrestrial amphipods live on the surface of mulch and moist ground (Fasulo 2008). Many of the habitat features of terrestrial amphipods are similar to those of isopods. These little animals are most commonly noticed by their strong, rapid jumps upon being disturbed.

7.1.2. Taxonomy of alien terrestrial crustaceans

Thirty-eight species belonging to ten different families were recorded during this study. The four most commonly represented families (all belonging to Isopoda) are Trichoniscidae (seven species), Porcellionidae (five species), Philosciidae and Armadillidiidae, both with five species (Figure 7.1.1.). Two main categories were considered:

- Aliens *to* Europe, including 17 crustacean species originating from other continents (Table 7.1.1).
- Aliens *in* Europe, represented by 21 crustacean species native to a region of Europe but introduced in another European region to which they are not native. Several other species considered as cryptogenic or cosmopolitan are probably also aliens in some parts of Europe. However, in most cases it was not possible to distinguish their alien range from the native one. Below only those species we classify as aliens *in* Europe:

Armadillidiidae: *Armadillidium assimile* Budde-Lund, 1879, *Armadillidium kossuthi* Arcangeli, 1929, *Armadillidium nasatum* Budde-Lund, 1885, *Armadillidium vulgare* (Latreille, 1804);

- Oniscidae: *Oniscus asellus* Linnaeus, 1758;
- Philosciidae: *Chaetophiloscia cellaria* (Dollfus, 1884);
- Platyarthridae: *Platyarthrus schoblii* Budde-Lund, 1885;
- Porcellionidae: *Porcellio dilatatus* Brandt, 1833, *Porcellio laevis* Latreille, 1804, *Porcellio scaber* Latreille, 1804, *Porcellionides pruinosus* (Brandt, 1833), *Proporcellio vulcanius* Verhoeff, 1908;
- Schiziidae: *Paraschizidium coeculum* (Silvestri, 1897);

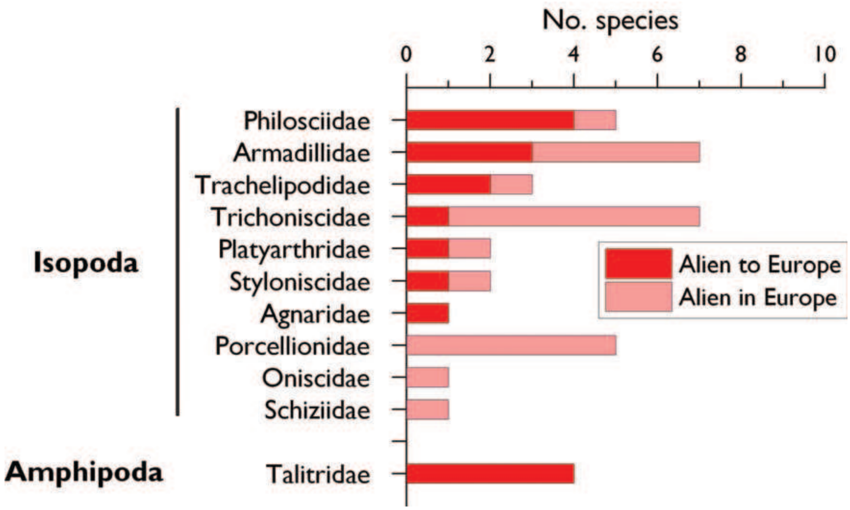

Figure 7.1.1. Taxonomic overview of the Isopoda and Amphipoda species alien *to* and Alien *in* Europe.

- Styloniscidae: *Cordioniscus stebbingi* (Patience, 1907);
- Trachelipidae: *Agabiformius lentus* (Budde-Lund, 1885);
- Trichoniscidae: *Androniscus dentiger* Verhoeff, 1908, *Buddelundiella cataractae* Verhoeff, 1930, *Haplophthalmus danicus* Budde-Lund, 1880, *Metatrichoniscoides leydigi* (Weber, 1880), *Trichoniscus provisorius* Racovitza, 1908, *Trichoniscus pusillus* Brandt, 1833.

Some of the species above have proved to be very successful colonizers and are currently considered as part of the native fauna in parts of Europe, e.g. in Hungary. However, their synanthropic nature and their extremely wide distribution range suggest a long colonisation history as it is the case for *Armadillidium vulgare*.

In the remainder of this chapter, we will focus mainly on the species alien *to* Europe.

7.1.3. Temporal trends of introduction in Europe of alien terrestrial crustaceans

The total number of crustaceans alien *to* Europe has slowly increased during the 20th and the early 21st centuries, but without any acceleration in the rate of arrival. Two alien species were first discovered in Europe in the 19th century, about nine species in the first half of the 20th century and only five species since then. The majority of these alien species have been found in several other countries after their discovery in Europe. However, the number of occupied countries over time has grown steadily rather than exhibiting exponential growth.

A similar pattern is apparent for woodlice species alien *to* Europe. However, because of sparcer information on this group, the date for the first introduction is roughly known for only approximately 50% of species. To our knowledge, at least six species of woodlice classified as aliens of Europe were noticed in the first half of the 20th century and only five more species since then.

Thus, unlike many other invertebrate phyla, the temporal trend in alien crustaceans (both intra-European and alien) has shown no marked changes during recent decades. As "silent invaders" (Hornung et al. 2007) no terrestrial crustaceans are classified as pests in Europe; they are elusive animals. We suspect frequently a large gap between the date of introduction and "discovery" of alien woodlice species. For example, during an intense eight year survey of the isopod fauna in a large region representing 15% of Hungary, three new alien species for this country were found (Farkas 2007).

To conclude, the atypically gradual trend in the number of alien terrestrial Crustacea in Europe could be an artefact of incomplete knowledge. Because of both the increasing worldwide trade in ornamental plants and the general ecology of terrestrial crustaceans (i.e. often hidden in soils), it is more realistic to expect a future exponential increase in the number of alien species (especially intra-European aliens).

7.1.4. Biogeographic patterns of the alien Crustaceans

7.1.4.1. Origin of the alien species

Species alien *to* Europe almost all originate from sub-tropical or tropical areas (Table 7.1.1.). Only one species – *Protracheoniscus major* (Dollfus, 1903)- is likely to be native from Central Asia. For several species, their ranges are poorly known (they are also often introduced in other tropical areas). However, several species do have a precise origin. The most widely distributed alien woodlouse in Europe is the tropical American *Trichorhina tomentosa* (Budde-Lund, 1893), while the most widely distributed amphipod is *Talitroides alluaudi* Chrevreux, 1901. It should be noted that a least six of the seventeen alien species were originally described from Europe (Great Britain, France and Germany) after their introduction.

The crustaceans alien *in* Europe generally originate from the Mediterranean basin (seven species), from western and south-western Europe (five species).

7.1.4.2 Distribution of the alien species in Europe

Within Europe, Crustaceans of alien origin have mainly been recorded in western countries, where they appeared first. The four countries with most species are Great Britain (11 species), the Netherlands (10 species) and Germany (nine species) (Figure 7.1.2). Comparatively few alien species have been recorded in central and eastern Europe to date (e.g. only four species in Hungary). In this part of Europe, the Central-Asian *P. major* is one of the most widespread alien crustaceans. The high number of aliens in western European countries may be linked to the high number of scientists and the intensity of soil research (Hornung 2009).

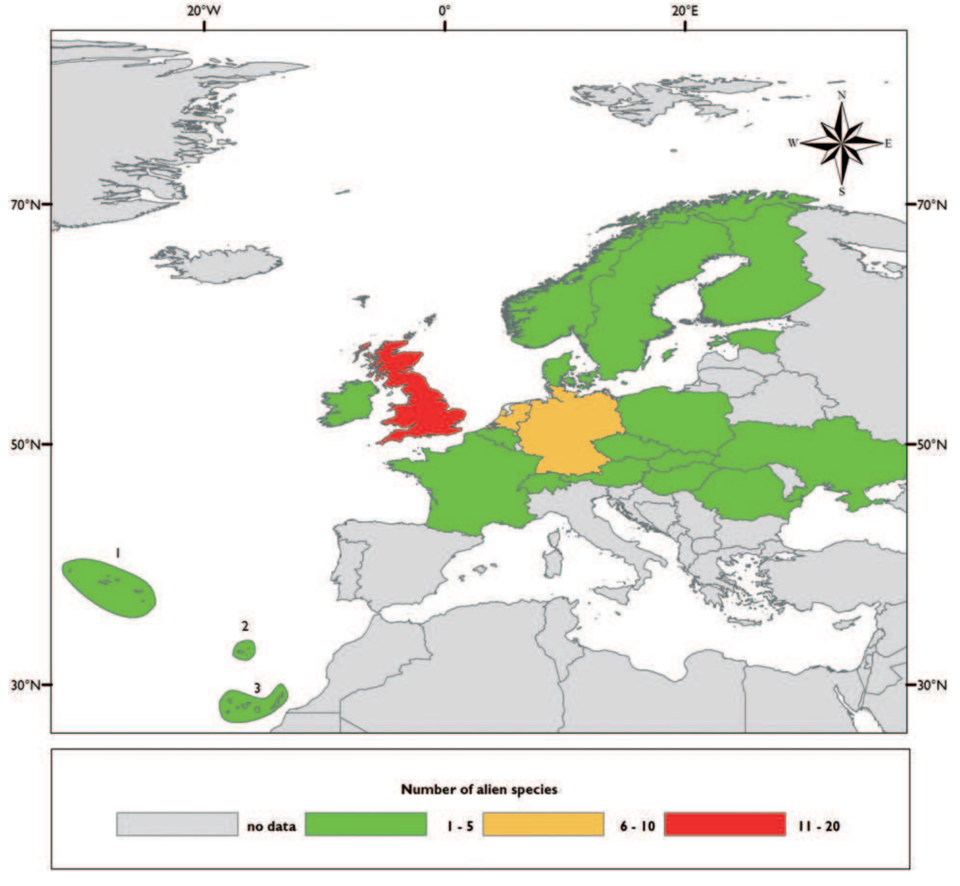

Figure 7.1.2. Colonization of continental European countries and main European islands by myriapod species alien to Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

There are only very few records of alien crustaceans on European islands. *Trichoniscus pusillus* has been reported from the Azores and Madeira, *T. provisorius* and *A. assimile* from the Azores but these species are native of Continental Europe. To our knowledge, the only alien aliens recorded on islands are talitrids, *Arcitalitrus dorrieni* (Hunt, 1925) in Scilly and Guernsey, *Talitroides topitotum* (Burt, 1934) in the Azores and Madeira, and *T. alluaudi* in the Azores and the Canaries. All these species occur outdoors and are therefore considered as naturalised. The rarity of alien terrestrial crustaceans on European islands is likely to be due to the primarily introduction route being major greenhouses in large metropolitan cities (see below).

Crustaceans classified as aliens of Europe are typically species which have expanded their range approximately northwards and eastwards. The eastern and central countries have a higher number of these species than more westerly countries of Europe. For example, Germany and the Czech Republic, taken together, have nine species of alien woodlice of European origin, about 45% of the total in this category.

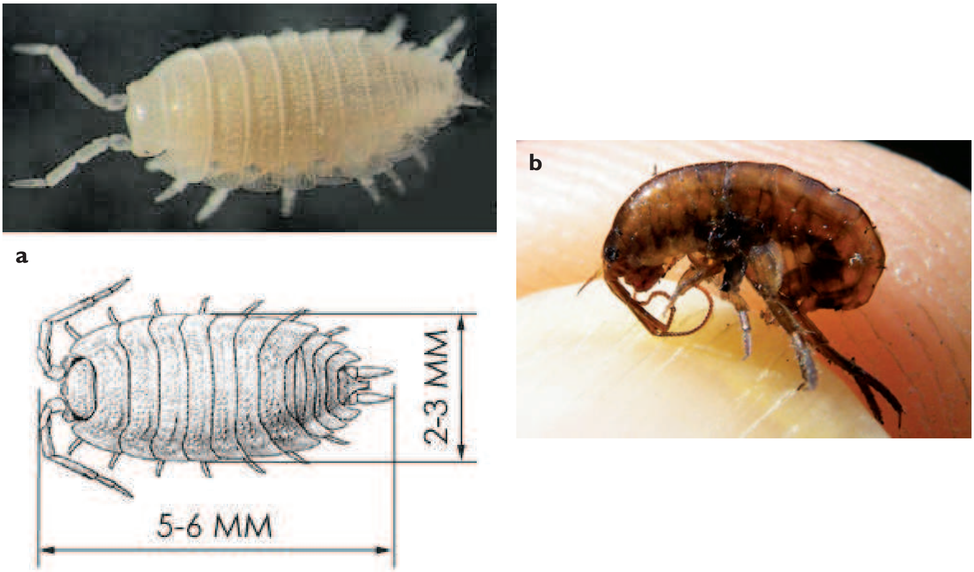

Figure 7.1.3. Alien terrestrial crustaceans. **a** *Trichorhina tomentosa* (Isopoda, woodlice) (credit: Vassily Zakhartchenko) **b** *Arcitalitrus dorrieni* (Amphipoda, lawn shrimp) (Credit: John I. Spicer).

A striking example of successful colonization and establishment of such species is given by *A. nasatum*. This woodlouse is believed to be native to Italy, southern France and Spain (Vandel 1962). Since the start of the 20th century, it has been introduced into greenhouses in a number of additional countries of Northern and Central Europe (e.g. Denmark, Finland, Germany, Hungary, Poland, Slovakia, Sweden), making this species one of the most widely distributed alien woodlice of Europe. Moreover, numerous reports highlight the successful establishment of outdoor populations in several western and central European countries (e.g. the Netherlands, Czech Republic, Romania, Slovenia) (Berg et al. 2008, Giurginca 2006, Navrátil 2007, Vilisics and Lapanje 2005).

Some of the aliens of Europe have also invaded other continents and can be considered as very successful invaders. The most notable ones are *A. vulgare*, *P. scaber* and *P. pruinosus*. *Armadillidium vulgare* and *P. pruinosus* are probably native from Mediterranean regions. In northern temperate parts of Europe, these species are restricted to synanthropic habitats (e.g. gardens, cellars, compost heaps). *P. pruinosus* is one of the woodlice that has been spread most by man across the world (Vandel 1962) and can now be considered as “synanthropically cosmopolitan” (Schmalfuss 2003).

A consequence of the dominance of Mediterranean origin for species classified as aliens of Europe is their decreasing number towards the north of the continent (Vilisics et al. 2007). In the northernmost countries of Europe (e.g. Finland (Vilisics and Terhivuo 2009)) only the most tolerant habitat-generalists, as well as intra-European aliens, are able to become successfully established.

7.1.5. Pathways of introduction of alien terrestrial Crustaceans

Because a great majority of the first isopod introductions were recorded in greenhouses, botanical gardens or urban parks, it is clear that many were associated with passive transport of soil, plants or compost. With few visible effects in such biotopes, terrestrial crustaceans colonize and spread as undetected "silent invaders" (Hornung et al. 2007). Thus, most introductions were unintentional. The one known exception is the spreading of *T. tomentosa*, commonly sold as pet food, triggered by trading activity in Europe. This probably explains why, among all the alien crustaceans, *T. tomentosa* is the most widespread species in Europe.

Another interesting case is the Mediterranean species *P. schoblii*. This myrmecophylous woodlouse is a commensal of the ant *Lasius neglectus* Van Loon, Boomsma & Andrásfalvy, 1990 and was first recorded in Hungary in 2001, a few years after the introduction of the ant. *P. schoblii* was probably introduced at the same time as its ant host (Tartally et al. 2004). It has since been found regularly (Hornung et al. 2005, Tartally et al. 2004, Vilisics 2007, Vilisics et al. 2007) and is now considered established, as is *L. neglectus*.

7.1.6 Ecosystems and habitats invaded in Europe by alien terrestrial Crustaceans

To our knowledge, the only alien crustaceans invading natural habitats are three talitrid species. *Arcitalitrus dorrieni* has invaded leaf litter understoreys of deciduous woodlands in Great Britain and Ireland (Cowling et al. 2003, Vader 1972). *Talitroides alluaudi* is known outdoors in the Canary Islands, and *T. topitotum* in the Madeira Islands, both species in the Azores (Vader 1972). All other species are generally limited to highly artificial habitats and artificial ecosystems: mostly greenhouses, urban parks and houses (especially cellars). The proportion of introduced isopods can be very high in urban areas. A study in Budapest revealed that 35% of the total species (n = 28) were introduced (Vilisics and Hornung 2009). The major settlements of Hungary were characterised as "hotspot for non-native species" (Hornung et al. 2008). This could certainly be applied to many major cities in other European countries.

For the tropical species, especially those recorded only once or twice in Europe, they may not be considered as established (Table 7.1.1.) since their survival is completely dependent on warm greenhouses.

Among all alien woodlice, none have spread to more natural habitats. However, the situation is different for intra-European woodlice native to southern or Mediterranean Europe. These established aliens can successfully expand by dispersal from very disturbed areas (where they were originally introduced) to more semi-natural habitats in rural-suburban zones (Vilisics and Hornung 2009). With global warming and the large-scale disturbance of biomes in Europe, that trend could increase, especially for the species with large ecological spectra.

7.1.7. Ecological and economic impact of alien terrestrial Crustaceans

Alien crustaceans in Europe are not known to carry diseases or to have an impact on native species and natural habitats. Further, they have no economical impact. Based on existing literature, the occurrence of alien woodlice is strictly bound to the urban environment (e.g. greenhouses, botanical and private gardens); alien terrestrial isopods do not yet seem able to survive or to expand to more natural ecosystems.

The case of the alien amphipod *A. dorrieni* is quite different. Terrestrial amphipods are known to have many effects on the soil and leaf litter (Friend and Richardson 1986). *Arcitalitrus dorrieni* has invaded deciduous and coniferous woodlands in western parts of Great Britain. In Ireland, a study showed that 24.7% of annual litter fall in a coniferous woodland was ingested by this species. It is suggested that "this introduced species plays a more important role than native macrofaunal species in nutrient turnover in this particular woodland habitat" (O'Hanlon and Bolger 1999). It is possible that other, as yet undetected, ecological impacts are likely.

Terrestrial crustaceans can represent a large percentage of biomass and abundance in the soil macrofauna (Gongalsky et al. 2005). Thus any successful invasion by a terrestrial alien crustacean could induce some disturbance if it established in relatively natural habitats. For example, in a forested area of Florida, a study on the introduced European woodlouse *A. vulgare* showed that this species' activity "had a strong effect on the chemistry of the mineral layer" (Frouz et al. 2008) and concluded that in some cases it may significantly alter soil conditions".

Woodlice classified as aliens *of* Europe are usually associated with synanthropic habitats and often gain dominance in urban environments (e.g. urban parks, villages, private gardens). The successful colonisation of human- influenced biotopes may lead to the uniformity of local Isopod assemblages. With the decrease of native species in the urban isopod fauna, an ongoing process of biotic homogenisation is prevalent in cities across Europe (Szlávecz et al. 2008, Vilisics and Hornung 2009).

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References

Allspach A (1992) Die Landasseln (Crustacea: Isopoda: Oniscidea) Hessens. *Naturschutz heute* 12: 1–146.

Berg MP, Soesbergen M, Tempelman D, Wijnhoven H (2008) *Verspreidingsatlas Nederlandse landpissebedden, duizendpoten en miljoenpoten (Isopoda, Chilopoda, Diplopoda)*. *European Invertebrate Survey*. Amsterdam: Nederland Vrije Universiteit, Afdeling Dierecologie.

Calman WT (1912) On a terrestrial amphipod from Kew Gardens. *Annals and Magazine of Natural History* 8: 132–137.

Chevreux E (1896) Recherches zoologiques dans les serres du Museum de Paris. sur un amphipode terrestre exotique, *Talitrus alluaudi* nov. sp., acclimate dans les serres du Jardin des Plantes de Paris. *Feuille des jeunes naturalistes* 3: 112–113.

Cowling JE, Spicer JI, Weeks JM, Gaston KJ (2003) Environmental tolerances of an invasive terrestrial amphipod, *Arcitalitrus dorrieni* (Hunt) in Britain. *Comparative Biochemistry and Physiology Part A* 136: 735–747.

Cowling JE, Spicer JI, Gaston KJ, Weeks JM (2004) Current status of an amphipod invader, *Arcitalitrus dorrieni* (Hunt, 1925), in Britain. *Journal of natural history* 38: 1665–1675.

Cowling JE, Weeks, Spicer JI, Gaston KJ (2004) Physiological tolerances of the euterrestrial amphipod Arcitalitrus dorrieni (Hunt) as a key to its geographical distribution? A test using mesocosms. *Comparative Biochemistry and Physiology, Part A* 139: 251–259.

Dollfus A (1896a) Recherches zoologiques dans les serres du Muséum de Paris. *Feuille des jeunes naturalistes* 30: 90–94.

Dollfus A (1896b) On West-Indian terrestrial Isopod Crustaceans. *Proceedings of the General Meetings for Scientific Business of the Zoological Society of London for the year 1896*: 388–400.

Dudich E (1926) Trópusi rák Budapesten. *Természettudományi Közlöny*, 58: 293–295.

Dudich E (1933) Faunisztikai jegyzetek (Faunistiche Notizen) IV. *Állattani Közlemények* 30: 120–129.

Dyduch T (1903) Materialien zu einer Isopodenfauna Galiziens. *Bulletin international de l'Académie des Sciences et des Lettres de Cracovie*: 61–64.

Dominiak B (1970) Badania nad równonogami Polski. *Fragmenta faunistica (Warsaw)* 15: 401–472.

Edney E (1953) The woodlice of Great Britain and Ireland. A concise systematic monograph. *Proceedings of the Linnean Society London* 164: 49–98.

Farkas S (2007) The terrestrial isopod fauna of South Transdanubia (Hungary). *Somogyi Múzeumok Közleményei. B - Természettudomány* 17: 159–168.

Fasulo TR (2008) Terrestrial Amphipods or "Lawn Shrimp" (Crustacea: Amphipoda). University of Florida, Featured Creatures Website. http://creatures.ifas.ufl.edu [accessed July 2001, revised 2008].

Ferrara F, Taiti S (1982) A new Philosciid from eastern Africa (Crustacea, Oniscoidea). *Revue Suisse de zoologie* 89: 439–442.

Flasarová M (1986) Isopoda (Asellota, Oniscoidea) of the Little Carpathians. In: Nosek J (Ed) *The Soil Fauna of the Little Carpathians*, Bratislava, 183–216.

Flasarová M (1988) Zur Kenntnis der Isopoden Mittelböhmens (Crustacea, Isopoda, Asellota et Oniscidea). *Faunistische Abhandlungen (Dresden)* 15: 119–130.

Flasarová M (1995) Die isopoden Nordwestböhmens (crustacea: Isopoda: Asellota et oniscidea). *Acta Scientarum naturalium (Brno)* 29: 1–156.

Forró L, Farkas S (1998) Checklist, preliminary distribution maps, and bibliography of woodlice in Hungary (Isopoda: Oniscidea). *Miscellanea Zoologica Hungarica* 12: 21–44.

Foster NH (1911) On two alien species of woodlice found in Ireland. *The Irish Naturalist* 20: 154–156.

Foster NH, Pack-Beresford DR (1913) Additions to the distributional records of woodlice in Ireland. *The Irish Naturalist* 22: 45–48.

Frankenberger Z (1959) *Fauna ČSR, Svazek 14. Stejnonožci suchozemští - Oniscoidea.* Praha: NČSAV.

Friend JA, Richardson AMM (1986) Biology of terrestrial Amphipods. *Annual Review of Entomology*, 31: 25–48.

Frouz J, Lobinske R, Kalčík J, Arshad A (2008) Effect of the alien crustacean, *Armadillidium vulgare* (Isopoda), and other macrofauna on organic matter dynamics in soil microcosms in a hardwood forest in central Florida. *Florida entomologist* 91: 328–331.

Giurginca A (2006) On some Oniscidea and Diplopoda from Bucharest, Romania. *Archives of Biological Sciences, Belgrade* 58: 31–35.

Gongalsky KB, Savin FA, Pokarzhevskii AD, Filimonova ZV (2005) Spatial distribution of isopods in an oak-beech forest. *European Journal of Soil Biology* 41: 117–122.

Grüner H (1966) Über *Protracheoniscus asiaticus* (Uljanin, 1875) und die verwandten Arten (Isopoda, Oniscoidea). *Mitteilungen des zoologischen Museums Berlin* 42: 307–319.

Gregory S (2009) *Woodlice and Waterlice (Isopoda: Oniscidea & Asellota) in Britain and Ireland*. Centre for Ecology & Hydrology. 175 pp.

Harding PT, Sutton SL (1985) *Woodlice in Britain and Ireland: distribution and habitat*. Huntingdon, UK: Institute of terrestrial ecology, Natural environment research Council. 151 pp.

Hassall M, Turner J, Rands M (1987) Effects of terrestrial isopods on the decomposition of woodland leaf litter. *Oecologia (*Berlin) 72: 597–604.

Holthuis LB (1945) Notes on terrestrial isopoda collected in Dutch greenhouses. *Zoologische Mededeelingen* 25: 43–54.

Holthuis LB (1947) On a small collection of isopod Crustacea from the greenhouses of the Royal Botanic Gardens, *Kew. Annals and Magazine of natural History*, Series 11, 13: 122–137.

Holthuis LB (1956) *Fauna van Nederland* 16. *Isopoda en Tanaidacea*. 16. Leiden, The Netherlands: AW Sijthoff's Uitgeversmaatschappij N.V. 280 pp.

Hornung E, Vilisics F, Sólymos P (2008) Low alpha and high beta diversity in terrestrial isopod assemblages in the Transdanubian region of Hungary. In: Zimmer M, Cheikrouha C, Taiti S (Eds) *Proceedings of the International Symposium of Terrestrial Isopod Biology*, 1–11.

Hornung E, Vilisics F, Tartally A (2005) Occurrence of *Platyarthrus schoblii* (Isopoda, Oniscidea) and its ant hosts in Hungary. *European Journal of Soil Biology* 41: 129–133.

Hornung E, Vilisics F, Szlávecz K (2007) Hazai szárazföldi ászkarákfajok (Isopoda, Oniscidea) tipizálása két nagyváros, Budapest és Baltimore (ÉK Amerika) összehasonlításának példájával. *Termeszetvedelmi Közlem enyek,* 13: 47–58.

Hornung E (2009) personal communication.

Hunt OD (1925) On the amphipod genus *Talitrus*, with a description of a new species from the Scilly Isles, *T. dorrieni* n. sp. *Journal of the Marine Biological Association of the United Kingdom* 13: 854–869.

Ilosvay G (1985) On the isopod, diplopod and chilopod fauna of the Zirc arboretum. *A Bakony természettudomanyi kutatásának eredményei* 16: 43–50.

Jędryczkowski W (1979) Synanthrope landisopoden (isopoda, oniscoidea) polens. *Fragmenta faunistica (Warsaw)* 25: 95–106.

Kesselyák A (1930a) Über isopoden. *Zoologischer Anzeiger* 91: 50–66.

Kesselyák A (1930b) Faunistisches uber Isopoden. *Zoologische Jahrbucher, Abteilung fur Systematik, Okologie und Geographie der Tiere* 60: 239–256.

Kontschán K (2004) Magyarország faunájára új ászkarák (*Reductoniscus constulatus* Kesselyák, 1930- Crustacea: Isopoda: Oniscidea) előkerülése az ELTE füvészkertjeből (Budapest). *Folia Historico Naturalia Musei Matraensis* 28: 89–90.

Korsós Z, Hornung E, Szlávecz K, Kontschán J (2002) Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. *Annales Historico-Naturales Musei Nationalis Hungarici* 94: 193–208.

Meinertz T (1934) Die Landisopoden Danemarks. II. Die Onisciden. *Zoologische Jahrbucher, Abteilung fur Systematik, Okologie und Geographie der Tiere* 66: 211–284.

Moore PG, Spicer JI (1986) On the status of *Arcitalitrus dorrieni* (Crustacea: Amphipoda) on the island of Colonsay, Inner Hebrides. *Journal of Natural History* 20: 667–680.

Navrátil M (2007) Stonožky, mnohonožky a suchozemští stejnonožci ve městě (Olomouc, Hodonín). Master's thesis, Univerzita Palackého v Olomouci.

Oliver PG, Meechan C (1993) *Woodlice*. Number 49 in Synopses of the British Fauna (N. S.). London: The Linnean Society of London.

Olsen KM (1995) *Cordioniscus stebbingi* (Patience, 1907) and *Trichorhina tomentosa* (Budde-Lund, 1893), two greenhouse woodlice (Isopoda, Oniscidea) new to Norway. *Fauna Norvegica Ser B* 42: 67.

O'Hanlon RP, Bolger T (1999) The importance of *Arcitalitrus dorrieni* (Hunt) (Crustacea: Amphipoda: Talitridae) in coniferous litter breakdown. *Applied soil ecology* 11: 29–33.

Pack-Beresford D, Foster N (1911) The woodlice of Ireland. Their distribution and classication. *Proceedings of the Royal Irish Academy* 29: 165–189.

Patience A (1907) On a new British terrestrial isopod. *Annals of Scottish natural History* 62: 85–88.

Patience A (1908) On a new British terrestrial isopod (*Trichoniscus linearis* sp. n.). *Annals and Magazine of Natural History* 8: 280–282.

Peart R, Lowry JK (2006) The amphipod genus *Arcitalitrus* (Crustacea: Amphipoda: Talitridae) of New South Wales forests, with descriptions of six new species. *Records of the Australian Museum* 58: 97–118.

Polk P (1959) Notes sur la distribution et la bibliographie des Oniscoidea de la Belgique. *Biologisch Jaarboek (Antwerpen)* 27: 452–460.

Radu VG (1960) Specii de losciide (izopode terestre) in fauna Republicii Populare Romine. *Studii şi Cercetări de Biologie. Academia Republicii Populare Romine, Filiala Cluj* 11: 269–275.

Schmalfuss H (2003) World catalog of terrestrial isopods (Isopoda: Oniscidea). *Stuttgarter Beiträge zur Naturkunde serie A* 654: 341. Revised and updated version. http://www.oniscidea-catalog.naturkundemuseum-bw.de/Cat_terr_isop.pdf.

Schmölzer K (1974) *Catalogus Faunae Austriae, Teil 8e, Isopoda*. Vienna, pp. 1–16.

Semenkevitsh J (1931) Isopoda terrestria der Umgegend von Kiew. *Mémoires de la Classe des Sciences naturelles et techniques de l'Academie des Sciences d'Ukraine* 5: 3–16.

Spicer JI, Tabel H (1996) Notes on the occurrence of the introduced landhopper *Arcitalitrus dorrieni* (Hunt, 1925) on Guernsey, Channel Islands. *Journal of natural history* 30: 1625–1632.

Soesbergen S (2003) *Venezillo parvus* en *Synarmadillo* spec., twee nieuwe landpissebedden in Nederland (Crustacea: Isopoda: Armadillidae). *Nederlandse faunistische Mededelingen* 18: 97–101.

Soesbergen M (2005) En de naam is... *Synarmadillo pallidus* (Crustacea: Isopoda: Armadillidae). *Nederlandse faunistische Mededelingen* 22: 123–126.

Stock JH, Biernbaum CK (1994) Terrestrial Amphipoda (Talitridae) from Ascension and Saint Helena (South Central Atlantic). *Journal of natural history* 28: 795–811.

Strouhal H (1929) Über einige Arten der Gattung *Protracheoniscus* Verh. (Isop. terr.). *Annalen des naturhistorischen Museums in Wien* 43: 1–12.

Strouhal H (1951) Die österreichischen Landisopoden, ihre Herkunft und ihre Beziehungen zu den Nachbarländern. *Verhandlungen der zoologisch-botanischen Gesellschaft Wien* 92: 116–142

Sutton SL (1980) *Woodlice*. New York: Pergamon Press.144 pp.

Szlávecz K, Csuzdi C, Korsós Z, Hornung E, Vilisics F (2008) *Earthworms, Isopods and Millipedes on the urban landscape: Patterns in European and American cities*. In: Book of Abstracts of the 3rd Conference of the Competence Network Urban Ecology 'Urban Biodiversity and Design', Erfurt, Germany. May 2008, 234.

Tartally A, Hornung E, Espadaler X (2004) The joint introduction of *Platyarthrus schoblii* (Isopoda: Oniscidea) and *Lasius neglectus* (Hymenoptera: Formicidae) into Hungary. *Myrmecologische Nachrichten* 6: 61–66.

Uteseny K (Taiti S. det.) (2009) Unpublished record.

Vader W (1972) Terrestrial Amphipoda collected in greenhouses in the Netherlands. *Zoologische Bijdragen* 13: 32–36.

Vandel A (1960) *Faune de France 64. Isopodes terrestres (première partie).* Paris : Fédération Française des Sociétés de Sciences Naturelles.

Vandel A (1962) *Faune de France66. Isopodes terrestres (deuxième partie).* Paris : Fédération Française des Sociétés de Sciences Naturelles.

Verhoeff K (1928) Über stenonisciden. *Zoologischer Anzeige* 79: 58–64.

Verhoeff K (1930) Zur Kenntnis osteuropaischer Isopoden. Zoologische Jahrbucher. *Abteilung fur Systematik, Okologie und Geographie der Tiere* 59: 1–64.

Verhoeff K (1937) Über einige neue und bekannte isopoda terrestria. *Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin 1937*: 411–430.

Vilisics F (2007) New and rare species in the isopod fauna of Hungary (Crustacea, Isopoda, Oniscidea): results of eld surveys and revisions. *Folia Historico-naturalia Musei Matraensis* 31: 115–123.

Vilisics F, Elek Z, Lövei GL, Hornung E (2007) Composition of terrestrial isopod assemblages along an urbanisation gradient in Denmark. *Pedobiologia* 51: 45–53.

Vilisics F, Hornung E (2009) Urban areas as hot-spots for introduced and shelters for native isopod species. *Urban ecosystems* 12: 333–345.

Vilisics F, Lapanje A (2005) Terrestrial isopods (Isopoda: Oniscidea) from the Slovenian karst. *Natura Sloveniae*, 71: 13–21.

Vilisics F, Sólymos P, Hornung E (2007) A preliminary study on habitat features and associated terrestrial isopod species. In: Tajovský K, Schlaghamerský J, Pižl V (Eds) *Contributions to Soil Zoology in Central Europe II*. České Budějovice: Institute of Soil Biology, Biology Centre, Academy of Sciences of the Czech Republic, 195–199.

Vilisics F, Terhivuo J (2009) Inspection on materials contributing to the knowledge of terrestrial Isopoda (Crustacea, Oniscidea) in Finland. *Memoranda Societatis pro Fauna et Flora Fennica* 85: 9–15.

Wouters K, Tavernier JM, Meurisse L (2000) Distribution and bibliography of the terrestrial Isopoda (Crustacea) of Belgium. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 70: 195–205.

Zimmer M (2002) Nutrition in terrestrial isopods (Crustacea: Isopoda): an evolutionary-ecological approach. *Biological Reviews* 77: 455–493.

Table 7.1.1. List and main characteristics of the Crustacean species alien *to* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 16/10/2009.

Order *Family*	*Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	References
Isopoda							
Agnaridae							
	Protracheoniscus major (Dollfus, 1903)	Detritivorous	Central Asia?	1903, PL/UA	AT, CZ, DE, EE, HU, PL, RO, SK, UA	J	Dudich (1926),Dudich (1933), Dyduch (1903), Dominiak (1970), Flasarová (1986), Flasarová (1988), Flasarová (1995), Forró and Farkas (1998), Frankenberger (1959), Ilosvay (1985), Schmölzer (1974), Semenkevitsh (1931), Strouhal (1929), Strouhal (1951), Verhoeff (1930)
Isopoda							
Armadillidae							
	Reductoniscus costulatus Kesselyák, 1930	Detritivorous	Pacific islands	1930, DE	DE, FR, GB, HU, NL	J	Berg et al. (2008), Grüner (1966), Holthuis (1947), Holthuis (1956), Kesselyák (1930a), Kesselyák (1930b), Kontschán (2004), Schmalfuss (2003), Soesbergen (2003), Vandel (1962), Verhoeff (1937)
	Synarmadillo pallidus Arcangeli, 1950	Detritivorous	Congo	2003, NL	NL	J	Berg et al. (2008), Schmalfuss (2003), Soesbergen (2003), Soesbergen (2005)
	Venezillo parvus (Budde-Lund, 1885)	Detritivorous	Tropical regions	2003, NL	GB, NL	J	Berg et al. (2008), Gregory (2009), Schmalfuss (2003), Soesbergen (2003)
Isopoda							
Philosciidae							
	Anchiphiloscia balssi (Verhoeffff, 28)	Detritivorous	East Africa	1928, DE	DE, NL	J	Berg et al. (2008), Ferrara and Taiti (1982), Holthuis (1945), Schmalfuss (2003), Verhoeff (1928)
	Benthana olfersii (Brandt, 1833)	Detritivorous	Brazil (Southeast)	?, DE	DE	J	Schmalfuss (2003)
	Burmoniscus meeusei (Holthuis, 1947)	Detritivorous	Asia	1947, GB	GB	J	Harding and Sutton (1985), Holthuis (1947)

Order Family	Species	Regime	Native range	1st record in Europe	Invaded countries	Habitat	References
	Burmoniscus orientalis Green, Ferrara & Taiti, 1990	Detritivorous	Asia	2005, AT	AT	J	Uteseny (2009)
Isopoda ***Platyarthridae***							
	Trichorhina tomentosa (Budde-Lund, 1893)	Detritivorous	America (Tropical)	1896, FR	AT, CH, BE, CH, CZ, DE, FR, GB, HU, IE, NL, NO, PL[1]	J	Berg et al. (2008), Dollfus (1896a), Foster (1911), Foster and Pack-Beresford (1913), Harding and Sutton (1985), Holthuis (1945), Jedryckowsky (1979), Korsós et al. (2002), Meinertz (1934), Olsen (1995), Pack-Beresford and Foster (1911), Polk (1959), Schmalfuss (2003), Verhoeff (1937), Wouters et al. (2000)
Isopoda ***Styloniscidae***							
	Styloniscus spinosus (Patience, 1907)	Detritivorous	Madagascar, Mauritius	1907, GB	GB	J	Edney (1953), Harding and Sutton (1985), Patience (1907), Schmalfuss (2003)
Isopoda ***Trachelipodidae***							
	Nagurus cristatus (Dollfus, 1889)	Detritivorous	Pantropical	1956, NL	DE, GB, NL, RO	J	Allspach (1992), Berg et al. (2008), Harding and Sutton (1985), Holthuis (1956), Oliver and Meechan (1993), Radu (1960), Schmalfuss (2003)
	Nagurus nanus Budde-Lund, 1908	Detritivorous	Tropical regions	1985 GB	GB, IE	J	Foster (1911), Foster and Pack-Beresford (1913), Harding and Sutton (1985), Schmalfuss (2003), Sutton (1980)
Isopoda ***Trichoniscidae***							
	Miktoniscus linearis (Patience, 1908)	Detritivorous	USA (East) ?	1908,GB	DE, GB	J	Kesselyák (1930a), Patience (1908), Schmalfuss (2003), Vandel (1962)

Order *Family*	*Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	References
Amphipoda *Talitridae*							
	Arcitalitrus dorrieni (Hunt, 1925)	Detritivorous	Australia (East)	1925, GB	GB, IE, NL	G1, J	Cowling et al. (2003), Cowling et al. (2004a), Cowling et al. (2004b), Hunt (1925), Moore and Spicer (1986), Peart and Lowry (2006), Spicer and Tabel (1996)
	Brevitalitrus hortulanus Calman, 1912	Detritivorous	Tropical regions?	1912, GB	GB, NL	J	Calman (1912), Friend and Richardson 1986, Vader (1972)
	Talitroides alluaudi (Chevreux, 1896)	Detritivorous	Tropical regions, Seychelles Isl.?	1896, FR	BE, CH, CZ, DE, DK, ES-CAN, FI, FR, GB, HU, NL, PL, PT-AZO, SE	G1, J	Chevreux (1896), Dudich (1926), Friend and Richardson (1986), Hunt (1925), Vader (1972)
	Talitroides topitotum (Burt, 1934)	Detritivorous	Indo-Pacific	1942, DE	DE, GB, NL, PT-AZO, PT-MAD	G,J	Friend and Richardson (1986), Stock and Biernbaum (1994), Vader (1972)

1 *Trichorhina tomentosa* is on sale as reptile food in many European pet shops.
After this table was established, Gregory (2009) mentioned the presence of two more alien species in Great Britain, *Styloniscus mauritiensis* (Barnard, 1936) (Styloniscidae) from Hawaii and Mauritius and *Setaphora patiencei* (Bagnall, 1908) (Philosciidae) from The Réunion and Mauritius islands.

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Myriapods (Myriapoda) Chapter 7.2

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Abstract

Alien myriapods in Europe have never been subject to a comprehensive review. Currently, 40 species belonging to 23 families and 11 orders can be regarded as alien to Europe, which accounts approximately for about 1.8% of all species known on the continent. Millipedes (Class Diplopoda) are represented by 20 alien species, followed by centipedes (Class Chilopoda) with 16, symphylans with 3 and pauropods with only 1. In addition there are numerous cases of continental species introduced to the Atlantic and Mediterranean islands or others of southern origin transported and established in North European cities. The earliest record of an alien myriapod dates back to 1836, although the introduction of some species into Europe could have begun already in historical times with an increase in trade between ancient Greeks and Romans with cities in the Near East and North Africa. In post-medieval times this process should have intensified with the trade between Europe and some tropical countries, especially after the discoveries of the Americas and Australia. The largest number of alien myriapods (25, excl. intercepted) has been recorded from Great Britain, followed by Germany with 12, France with 11 and Denmark with 10 species. In general, northern and economically more developed countries with high levels of imports and numerous busy sea ports are richer in alien species. The various alien myriapods have different origins, but most of them show tropical or subtropical links (28 species, 70%). Eight of them (20%) are widespread in the Tropical and Subtropical belts, eleven (circa 28%) are of Asian origin, seven show links with South and Central America, and one each originates from North America, North Africa, Australasia, and islands in the Indian Ocean. Ten myriapods are of unknown origin (cryptogenic). Only 12 species (*ca.* 30%) of all have established in the wild in Europe. At the present time alien myriapods do not cause serious threats to the European economy and there is insufficient data on their impact on native fauna and flora.

Keywords
Diplopoda, Chilopoda, Symphyla, Pauropoda, Europe, alien, invasions, intercepted species, biogeographical patterns

7.2.1. Introduction

Myriapods are terrestrial wingless arthropods with elongated bodies composed of more or less similar segments, most of which bear one or two pairs of legs. Four classes are recognised: Pauropoda, Symphyla, Chilopoda and Diplopoda. Approximately 15 000 species from nearly 160 families are currently known in the world. The Diplopoda is by far the most diverse group, comprising roughly 11 000 species (Adis and Harvey 2000). A total of 2,245 myriapod species or subspecies from 15 orders and 70 families are currently known in Europe (http://www.faunaeur.org/statistics.php), of which 1,529 are Diplopoda, 481 Chilopoda, 41 Symphyla and 125 Pauropoda. All members of the class Diplopoda (millipedes) have two pairs of legs per diplosegment for most segments. Several morphotypes have been recognised, i.e. juloid, polydesmoid, polyxenoid, platydesmoid and glomeroid (Kime and Golovatch 2000), of which the former two are especially rich in species both in Europe and worldwide. Most of the species are cylindrical or flattened dorsally, often with prominent lateral projections, generally medium- to large-sized (up to 8–9 cm in the genera *Pachyiulus* and *Eurygyrus*). Some species of the order Glomerida, or pill millipedes, are oniscomorph, capable of rolling up into a tight ball. Members of the order Polyxenida, or "dwarf millipedes", are minute in size and with peculiar hairs along the body arranged in groups and tufts like small pin-cushions or brushes. The number of legs varies between species, often (especially in juloids) even individually, the record being 375 pairs in the North American siphonophoridan species *Illacme plenipes* Cook & Loomis, 1928 (Marek and Bond 2006).

Species of the class Chilopoda (centipedes) have an elongated flattened trunk and bear one pair of legs per segment, with a total number ranging between 15 and 191 pairs. Centipede body length varies from a few millimeters in some species of genus *Lithobius* (*Monotarsobius*) to approximately 30 cm in the Neotropical species *Scolopendra gigantea* (Minelli and Golovatch 2001). All centipedes have a pair of poison claws, or forcipules, which represent modified first body appendages. About 3,500 valid species and subspecies from 5 orders and 22 families are known in the world (Minelli 2006, Edgecombe and Giribet 2007). The other two myriapod classes – Symphyla and Pauropoda – consist of very small species, with body length of 2–8 and 0.5–1.9 mm respectively, both still remaining very poorly studied. The number of described symphylans and pauropods in the world is roughly estimated to about 200 and 700, respectively (Adis and Harvey 2000).

Most millipedes, as well as all pauropods and symphylans, are phytophages, detritivores or saphrophages. A few millipedes can be regarded as omnivores, e.g. *Blaniulus guttulatus* (Fabricius, 1798), *Uroblaniulus canadensis* (Newport, 1844), or even predators, like *Apfelbeckia insculpta* (L. Koch, 1867), *Callipus foetidissimus* (Savi, 1819), and *Abacion magnum* (Loomis, 1843), which have been observed feeding on earthworms, flies and spiders (Hoffman and Payne 1969, Golovatch 2009). Other species feed on their own exuvia or fecal pellets (Minelli and Golovatch 2001).

Centipedes are mostly predatory, feeding on different available prey items in the soil (earthworms, enchytraeids, snails, slugs, small insects – both larvae and adults – and other arthropods). More details on the biology and ecology of millipedes, centipedes and the two other, smaller myriapod classes can be found in Hopkin and Read (1992), Lewis (1981), and Verhoeff (1933, 1934).

Little information is as yet available on the non-indigenous myriapods in Europe (DAISIE 2009, Roques et al. 2009). The most recent overview of alien organisms in Europe (see DAISIE 2009, p. 225) lists two centipedes (*Lamyctes emarginatus*, *Lamyctes caeculus*) and three millipedes (*Oxidus gracilis*, *Eurygyrus ochraceus*, *Sechellobolus dictyonotus* = *Paraspirobolus lucifugus*) as alien to Europe. Some papers have been, however, published on the ecology, morphology and post-embryonic development of several alien centipedes (Andersson 1984, 2006, Bocher and Enghoff 1984, 1975a, Negrea 1989) and millipedes (Enghoff 1975b, 1978, 1987, Golovatch et al. 2000, et al. 2002). Lists of alien species have been published for a few countries only, such as Germany (Kinzelbach et al. 2001), Austria (Gruber 2002, Gruber and Christian 2002), the Czech Republic (Šefrová and Laštůvka 2005), Switzerland (Wittenberg 2005), Italy (Zapparoli and Minelli 2005) and Great Britain (Barber 2009a, b). Increasing attention has been paid in the last decades to species which have accidentally arrived in Europe (see Barber 2009a, BBC News 2005, Christian and Szeptycki 2004, Gregory and Jones 1999, Lewis 1988, Lewis and Rundle 1988 for centipedes and Andersson and Enghoff 2007, Enghoff 2008a and Read 2008 for millipedes).

7.2.2. Taxonomy of the myriapod species alien to Europe

Altogether, 40 species belonging to 23 families and 11 orders can be regarded as alien to Europe (Table 7.2.1). This accounts approximately for about 1.8% of all myriapods known on the continent. Millipedes are represented by 20 alien species, followed by centipedes with 16, symphylans with 3 and pauropods with only 1. The relative proportion of alien species is highest in Symphyla (7.3%) and Chilopoda (3.3%), and the lowest in Pauropoda (0.8%) and Diplopoda (1.3%). The centipede family Henicopidae is the richest in alien species (5 species), followed by Scutigerellidae, Mecistocephalidae, Scolopendridae, Paradoxosomatidae and Pyrgodesmidae, each with three species. The remaining 17 families are represented by only one or two species each (Figure 7.2.1).

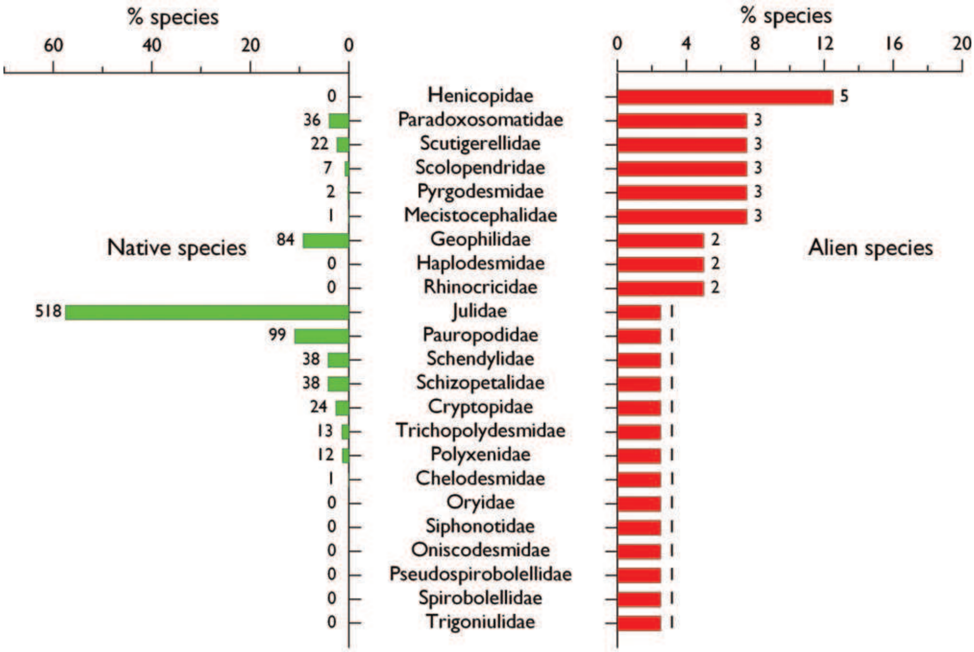

Figure 7.2.1. Relative importance of each family in the alien (right side) and native (left side) myriapod fauna in Europe. Number near the bar indicates the number of species. Families are listed in a decreasing order based on the number of alien or, in alternative, native species.

Striking is the absence of alien species in Europe of the species-rich order Spirostreptida since spirostreptidans, for instance *Hypocambala anguina* (Attems, 1900) and *Glyphiulus granulatus* Gervais, 1847, are quite widespread in the tropical countries and show a clear tendency to anthropochorism (Jeekel 1963, Shelley 1998).

Several myriapods have been intercepted at their arrival in Europe from consignments from other countries but have never managed to establish themselves. Barber (2009a) provided a list of centipede species captured and registered by the Central Science Laboratory (now FERA) in the UK when imported with exotic plants, fruits and luggage (Table 7.2.2). Two of them, *Lithobius forficatus* and *L. peregrinus*, are European natives which have long been introduced to Australia and New Zealand, so their interception in Great Britain is a clear case of re-introduction.

A similar list for intercepted millipedes examined by the Central Science Laboratories between 1975 and 2006 (S. Reid *pers. comm.*) is more substantial with some 85 entries over this period of time (Table 7.2.2). Of these 36 were records of *Oxidus gracilis* from a wide range of different parts of the world (W & S. Europe, Canary Islands, Israel, N., C. and S. America, Australia, China, Japan, Malaysia, Singapore, India, Nepal, N., W. and S. Africa and Madagascar). Other types found included members of the Polydesmida (dalodesmids, parodoxomatids, polydesmids), Spirosteptida (from Australia, New Zealand and Africa), Julidae and Blaniulidae. Amongst species from the latter two families were the NW European *Blaniulus guttulatus* and *Cylindroiulus* *londinensis* (both from Australia) and *Ommatoiulus moreletii* (originating in the Iberian Peninsula, introduced to Australia in 1953 and now a pest species there; in this list reported from both that country (tree fern) and South Africa (melon fruit)).

Man-aided introductions of species from one part of Europe to another have played a prominent role. One of the most common synanthropic centipedes in North Europe is the Mediterranean "house centipede" *Scutigera coleoptrata* (Linnaeus, 1758). It has been introduced to a number of North European cities, e.g., Copenhagen, Edinburgh, Aberdeen, Leiden, etc., where it survives only in buildings. The earliest record in the British Isles of this species is perhaps that by Gibson-Carmichael (1883) who recorded it from a paperworks near Aberdeen. It could have been established there already for 25 years and arrived in bundles of rags from South Europe (Barber 2009a); at the present time it is sporadically reported from inside buildings in various parts of Britain and seems to be common in houses in St. Peter Port (Guernsey) and St. Helier (Jersey) in the Channel Islands from where it has also been reported from outdoor sites. Other cases of south or central European species being introduced to northern countries that perhaps still survive only in buildings, hothouses, gardens or similar man-made habitats are: *Tuoba poseidonis* (Verhoeff, 1901) in Finland, *Dicellophilus carniolensis* (C.L. Koch, 1847), *Lithobius lucifugus* L. Koch, 1862, *Lithobius peregrinus* Latzel, 1880, *Haplopodoiulus spathifer* (Brölemann, 1897) and *Cylindroiulus salicivorus* Verhoeff, 1908 in Great Britain, *Cylindroiulus vulnerarius* (Berlese, 1888) in Sweden, *Pachyiulus varius* (Fabricius, 1781) in Norway, etc. (Barber 1995, Barber and Eason 1986, Barber and Keay 1988, Bergersen et al. 2006, Lee 2006, Read 2008).

Even within the same geographic area some indigenous species occur at localities that are not part of their primary distribution area, most probably as a consequence of accidental anthropogenic introductions. Examples are the records from Italy of *Lithobius infossus* Silvestri, 1894 near Padua (Minelli 1991), of *L. peregrinus* Latzel, 1880 in northeastern and central Italy (Minelli 1991, Zapparoli 1989, Zapparoli 2006), of *Pleurolithobius patriarchalis* (Berlese, 1894) in the Egadi, Pontine and Campania islands (Zapparoli and Minelli 1993), and of *Scolopendra cingulata* near Milan (Manfredi 1930).

Island invasions by continental species is another phenomenon worth mentioning. Eason in a study on the Icelandic fauna, concluded that most centipede and millipede species probably arrived by human transport (Eason 1970). Examples of recent introductions to Iceland are *Geophilus truncorum* Bergsøe & Meinert, 1866, *Polydesmus inconstans* Latzel, 1884, and *Brachydesmus superus* Latzel, 1884, which "… have only been found on Heimaey, one of the Vestman Islands, which supports a town and where casual introduction by human transport is likely: they have probably been introduced quite recently and the two millipedes seem still to be confined to the outskirts of the town". Regarding the other two possibly allochthonous species, *Lithobius forficatus* (Linnaeus, 1758), and *Lithobius erythrocephalus* C.L. Koch, 1847, Eason wrote, "these two species may be confined to the south owing to the relatively warm and humid southern climate, but their restricted distribution might also be explained by their having been introduced by Norse settlers ....". The first Norse settlements on Iceland were established in the ninth century A.D., so this must have happened after that time.

According to Enghoff (2008b), of the 21 species of centipedes recorded in Madeira 17 are introduced and 2 are probably introduced. High rates of introduction are also known for the Azores and Canary Islands (Borges and Enghoff 2005, Zapparoli and Oromi 2004) (Table 7.2.3). All symphylans on the Canary Islands have been considered as possibly introduced. Likewise, only two of 21 millipede species are considered native on the Azores (Enghoff and Borges 2005).

The geophilomorph centipede *Nyctunguis persimilis* Attems, 1932 was originally described from Turkey and has not been found there since in spite of the active work of the second author who has published several papers on the Turkish centipede fauna during the last 20 years. Taking into account that the species was recently found in synanthropic habitats in the outskirts of Vienna (Christian 1996) and that all other congeners occur in the Nearctic region, it is very likely that the type locality (the surroundings of Ankara, Turkey) is erroneous and the material was actually mislabeled (Zapparoli 1999).

Mecistocephalus maxillaris (Gervais, 1837), one of the first alien centipedes to be recorded in Europe, is another poorly known species. It was described from the gardens of the Muséum National d'Histoire Naturelle, Paris, and subsequently recorded from numerous places around the world. However, most of the records were certainly based on misidentifications with the morphologically similar *M. guildingii* or *M. punctifrons* actually being involved (Bonato et al. 2009). According to Bonato et al. (2009), most of the records in Europe e.g., those from Germany, Great Britain, France (not the type specimen but material taken subsequently from a greenhouse in the Paris Museum, cf. Brolemann 1930) and Portugal (Madeira), are referable to *M. guildingii*, while those from the Netherlands and Denmark require further clarification.

The actual taxonomic status and native range of *Ghilaroviella* cf. *valiachmedovi* remains uncertain. The same applies to the millipede *Chondrodesmus* cf. *riparius* which shows some differences from the original description by Carl (1914) and its identity cannot be clarified without a comprehensive review of the entire genus (Enghoff 2008a).

7.2.3. Temporal trends in the introduction of alien myriapod species to Europe

Introductions of alien myriapods into Europe probably began several centuries ago, even though a precise arrival date is hard to determine. Only 10 out of 40 species were recorded for the first time in Europe in the 19th century while most of the records date from the 20th (26 species) and 21st centuries (4 records).

Gervais was virtually the first person to record alien myriapods in Europe (Gervais 1836, 1837). He described the tropical millipede *Iulus lucifugus* (now *Paraspirobolus lucifugus*) and the geophilomorph centipede *Mecistocephalus maxillaris* from greenhouses of the Paris Museum. The means of arrival of both species remains obscure but must be linked to the establishment of the greenhouses and the planting of tropical flowers, perhaps already by the end of the 18th century. *P. lucifugus* has been subsequently recorded in intervals of around 60–70 years from greenhouses near Hamburg (Latzel 1895), Hortus Botanicus Amsterdam (Jeekel 1977), a greenhouse in Copenhagen (Enghoff 1975b), and more recently from the Tropical Biome at the Eden project (Lee 2006). This can hardly be regarded as reflecting the actual course of colonization but rather the date of investigation and the level of effort involved in each case.

The only alien millipede that has invaded some natural ecosystems in Europe and acclimatized is the East Asian species *Oxidus gracilis*. Perhaps the earliest records of this species in Europe are those of Tömösváry (1879) from the Margaret Island in Danube, Hungary, and of Latzel (1884) from greenhouses in Zeist, Utrecht, and Amsterdam in the Netherlands. Subsequently it was also found in Edinburgh in 1898 and in Kew Gardens in Great Britain (Evans 1900, Pocock 1902). In Finland the species was first recorded in 1900, but since the sample already contained several specimens the species must have arrived there at least two years earlier (Palmén 1949). The mechanism of dispersal of the species within Europe is certainly related to the trading and growing of tropical plants in the greenhouses as in some places this process must have happened more than once. According to Palmén (1949), the population of *O. gracilis* in the greenhouses of Hanko, South Finland went extinct during the period 1939–1943 when they were not kept warm. In 1946 a single female was found in a greenhouse with plants imported from Belgium, in 1947 its numbers increased considerably and the next year it was already very abundant in the whole greenhouse complex.

Golovatch (2008) suggested that the intense trade ties between the ancient town of Khersonesos in the Crimea and the town of Pergam (= Bergama), a major centre of red ceramics production of the time in present-day Turkey, as possible pathways for the introduction of *Eurygyrus ochraceus* in the Ukraine. He also pointed out that the Bulgarian population near Varna may owe its origin to the very active commerce in Roman times between Bergama and the colonies in Moesia (= currently northern Bulgaria and southern Romania), including Odessos (= Varna). The area and trade connections were already quite developed by the mid-4th century B.C. or even earlier, under ancient Greeks, so this introduction must have happened around that time.

Members of the genus *Lamyctes* are represented in Europe only by parthenogenetic populations. Males of *L. emarginatus* are known only from Macaronesia, New Zealand, Tasmania and Hawaii (see also Attems (1935) and Zapparoli (2002) for the record of a single male from Greece), while males of *L. coeculus* are only known from a greenhouse in Italy and from Cuba (Enghoff 1975a). Taking into account that the entire family Henicopidae is predominantly distributed in the Southern Hemisphere, and presuming that the regions where males are being found are the native areas of the species, *L. emarginatus* could have been introduced to Europe from one of the above regions, most likely from Australia or New Zealand. The earliest confirmed record is from Denmark in 1868 (see Meinert 1868). *Lamyctes coeculus* was first found in a greenhouse in Italy at the end of 19th century (Brölemann 1889), but its presence in the area would have been older. It has been recently found in Great Britain (Barber 2009b).

The earliest records of *Cylindroiulus truncorum* in Europe date from the 1920's and, according to Schubart (1925), the Central European populations are probably of relatively recent origin. In Finland it was first reported in 1945 and in the following three years its numbers increased considerably. It is completely lacking in older collections (Palmén 1949).

One of the recent introductions is the large Neotropical millipede *Chondrodesmus* cf. *riparius* which was first recorded in 2000 in a flowerpot in the telephone office of Umeå University, northern Sweden. It was found again elsewhere in Sweden in 2006 and, later, in January 2007, it was also recorded in a flowerpot with a palm (*Phoenix robbelini*) in an office in Copenhagen and in a flowerpot in Bonn (Enghoff 2008a). There are further records of the species from flowerpots in Germany and also a recent one in Norway (Göran Andersson in litt.), so it seems that the species is dispersing well with palm pots.

The study of the invertebrate fauna of Kew Gardens, Great Britain began already at the beginning of 20th century with papers by Pocock (1902, 1906) and continues today (Blower and Rundle 1980, 1986, Read 2008). Some of the species recorded by Pocock such as *Scolopendra morsitans*, *Trigoniulus corallinus* and *Asiomorpha coarctata* have not been re-found since then and most likely could not become established in Kew Gardens. At the same time *Paraspirobolus lucifugus*, *Amphitomeus attemsi*, *Cylindrodesmus hirsutus*, *Rhinotus purpureus* and *Pseudospirobolellus avernus*, species not previously known from Britain have been recorded recently in the Tropical Biome at the Eden project in Cornwall (Read 2008, Barber 2009b, Barber et al. 2010).

7.2.4. Biogeographic patterns of the myriapod species alien to Europe

Records of exotic species are not evenly distributed in Europe but this is mainly due to the different levels of investigation of this area. The highest number of species (25) has been recorded from Great Britain, followed by Germany with 12, France with 11 and Denmark with 10 alien myriapods (Figure 7.2.2). In general, northern and economically more developed countries with high levels of imports and numerous busy sea ports are richer in alien species. These countries also, in general, have poorer native faunas meaning that a small number of aliens can constitute a large percentage of the fauna. Several species are hitherto known in Europe from a single country only, e.g. *Prosopodesmus panporus*, *Pseudospirobolellus avernus*, *Tygarrup javanicus* and *Cryptops doriae*, which implies recent introductions or poor dispersal abilities. Others, such as *Eurygyrus ochraceus*, *Paraspirobolus lucifugus* and *Lamyctes coeculus*, have a larger but yet fairly restricted distribution limited to two or more countries. The most widespread species are the parthenogenetic centipede *Lamyctes emarginatus*, whose range in Europe spreads from the Urals to Iceland [outdoor species], and the bisexual millipede *Oxidus gracilis*, reported from 33 countries, including several Mediterranean islands.

The various alien myriapods have different origins, but most of them show tropical or subtropical links (28 species, 70%). Eight of them (20%) are widespread in the Tropical and Subtropical belts, very often introduced by human agency to islands and synanthropic areas on continents. Their native range cannot so far be determined with certainty (Figure 7.2.3). Eleven (circa 28%) alien myriapods are of Asian origin, the majority (10 species) having their native range in East or Southeast Asia, and only one from West Asia, namely Anatolia. *Cylindroiulus truncorum* is perhaps the only North African myriapod introduced to Europe just as *Brachyiulus pusillus* (Leach, 1814) so far is the only European julid introduced to North Africa (Akkari et al. 2009). The only species that seems to be an Australasian native (Australia and New Zealand) is *Lamyctes emarginatus*. Among henicopids, *Rhodobius lagoi* and *Ghilaroviella* cf. *valiachmedovi* are of particular interest being members of monotypic genera and the only representatives in Europe of the subfamily Anopsobiidae which comprises chiefly species with Gondwanan distribution patterns. Besides *Rhodobius*, four other monotypic genera represent the subfamily in the Northern Hemisphere, occurring in Vietnam, Japan, Kazakhstan, and Tajikistan (Edgecombe 2003, Farzalieva et al. 2004). Of Central or South American origin are seven species (circa 18%), and one each from North America and islands in Indian Ocean. The sole record of the pantropical geophilomorph centipede *Orphnaeus brevilabiatus* in Europe comes from Bohuslän, a Swedish province in the northern part of the W coast, where the animal was collected in the 19th century (Andersson et al. 2005).

Ten centipedes and millipedes have been considered as cryptogenic (= species of unknown origin which cannot be ascribed as being native or alien). Some of them such as the geophilid *Arenophilus peregrinus* and the schendylid *Nyctunguis persimilis*, which have only been reported from the Isles of Scilly, Great Britain and Austria respectively (Barber 2008, Christian 1996) whereas all the other species of these genera live in North America, are of likely Nearctic origins. Another suspected introduction of uncertain origin is *Nothogeophilus turki* which has hitherto been known only from Scilly and the Isle of Wight, Great Britain (Lewis et al. 1988) and represents a monotypic genus. However, we cannot completely exclude the possibility that some cryptogenic species suspected to be alien are actually native to Europe. Support for this notion we find in the scolopendromorph centipede *Theatops erythrocephalus* C.L. Koch, 1847, which occurs in various natural habitats (including caves) in the Pyrenees and the western part of the Balkans (with a gap between these geographic areas), while all its other four congeners occur in North America (Minelli 2006).

Unknown also is the origin of the symphylid *Hanseniella oligomacrochaeta* described from a hothouse in the Botanical Garden in Berlin; according to Scheller (2002), all species in the genus *Hanseniella* have tropical-subtropical distributions. The haplodesmid *Prosopodesmus panporus* is only known from the Royal Botanic Gardens in Kew, England, while its other described congener, *P. jacobsoni* Silvestri, 1910, is pantropical (Golovatch et al. 2009). Likewise, it is uncertain whether *Napocodesmus endogeus*, a millipede described solely from females collected in the garden of Cluj University, is a European native or not. According to Tabacaru et al. (2003), the generic allocation

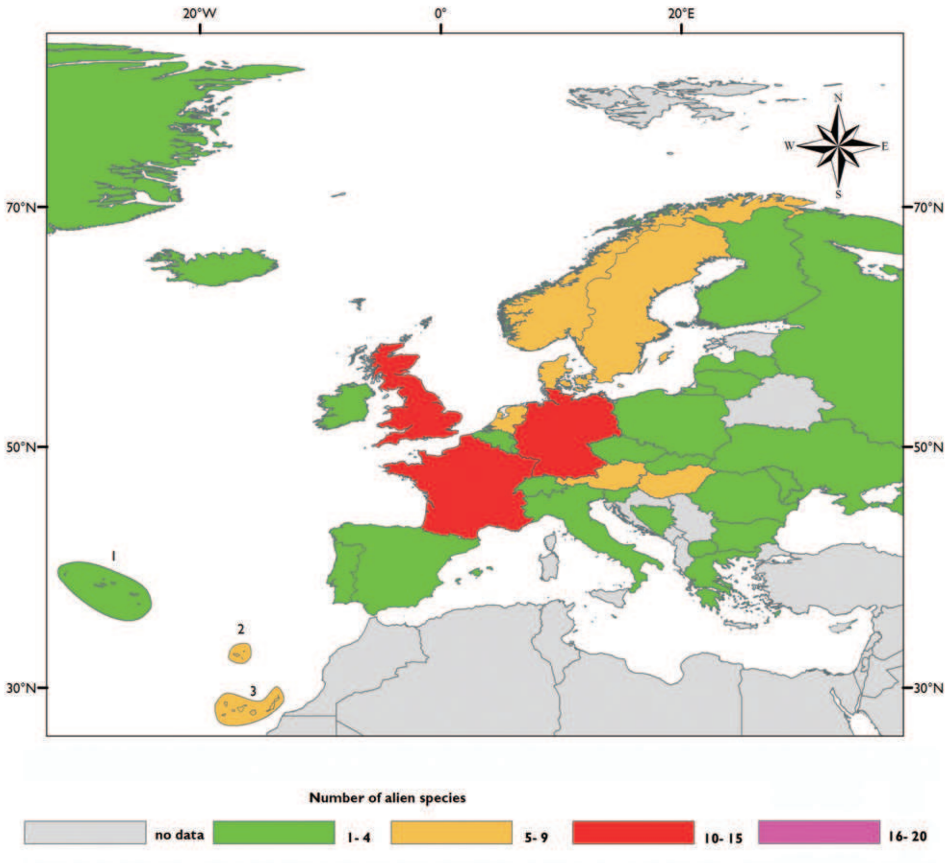

Figure 7.2.2. Colonization of continental European countries and main European islands by myriapod species alien to Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

of the second species described in the genus, *N. florentzae* Tabacaru, 1975, hitherto known from Romania and Moldova, is not certain and since there are no other records of *N. endogeus* in nature it might be an introduced species.

7.2.5. Pathways for the introduction of alien myriapod species in Europe

All of the alien myriapods have most probably been accidentally introduced to Europe with plant material in relation to human activities and trade between Europe and other continents such as Asia, Australasia and the Americas. This process must have begun with an increase in trade between ancient Greek and Romans with cities in Asia Minor and North Africa and should have intensified in post-medieval times with the trade between Europe and some East Asiatic countries (e.g. Japan, China) and the geographic discoveries of the Americas and, later, of Australia. This process is still going on with

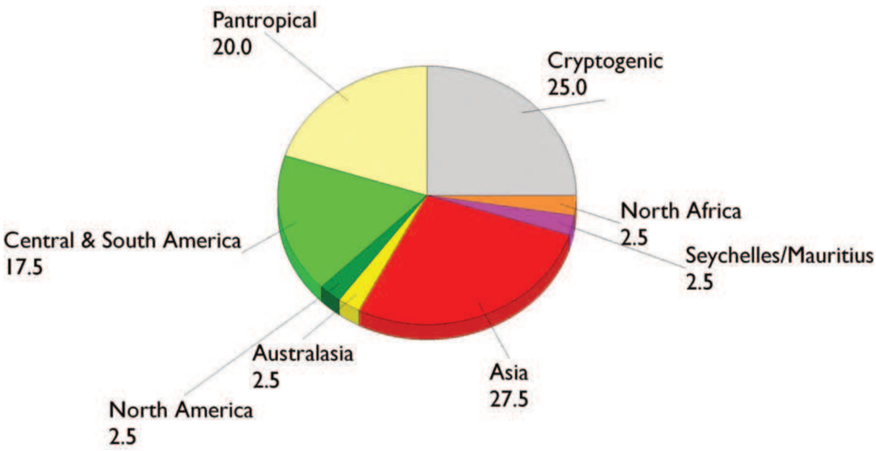

Figure 7.2.3. Geographic origin of the myriapod species alien to Europe (in percent).

the trade of tropical flowers and other plants and their cultivation in houses and greenhouses or with the importing of goods from tropical countries. Even large species could be transported this way, as is the recent case of the discovery of the largest centipede *Scolopendra gigantea*, found in 2005 in a house in London, which is thought to have arrived with a cargo of electrical goods or fruit (BBC News 2005). Pocock (1906) suggested the possible countries whence a variety of alien species found in Kew Gardens were introduced with their host plants: India (*Scolopendra morsitans*, *Mecistocephalus guildingii*), Sri Lanka (*Chondromorpha kelaarti*), Barbados (*Anadenobolus monilicornis*), Saint Vincent Island (*A. vincenti*).

The distribution of the alien diplopods in Europe shows that all the species living here in greenhouses are much more widespread compared to e.g. the restricted outdoor species *Eurygyrus ochraceus*. It is also likely that the obligate thelytokous parthenogenesis (= sexual reproduction giving rise to females only) shown in continental Europe by several of the exotic millipedes and at least one of the centipedes has facilitated their survival during transport and their establishment on the continent. However, bisexual populations are known from the Azores and the Canary Islands for *Lamyctes emarginatus* (Enghoff 1975a). Species from other centipede orders, such as the mecistocephalid *Tygarrup javanicus* also presumably reproduce by parthenogenesis since so far only females have been found in the hothouse at the Eden project, in Great Britain (Barber 2009b).

The number of exotic diplopods in Europe is far smaller (3–4 times) than that of European species introduced to other continents. Apparently, this could mean that the arrival and, especially, becoming resident in Europe is much more difficult than the converse process. The asymmetry has probably nothing to do with quarantine controls at European borders. Instead, it may be due to specific ecological and biological patterns exhibited by the successful invaders. Many of the alien millipedes and centipedes which have successfully invaded Europe be-

Figure 7.2.4. *Scolopendra gigantea* Linnaeus, 1758 [Chilopoda: Scolopendromorpha: Scolopendridae] caught in 2005 in apartment in London, perhaps arrived with a cargo of electric goods or fruit. Source: BBC News: http://news.bbc.co.uk/go/em/fr/-/1/hi/england/london/4201634.stm

Figure 7.2.5. *Tygarrup javanicus* Attems, 1929 [Chilopoda: Geophilomorpha: Mecistocephalidae]. United Kingdom: Eden Project, Cornwall. Credit: Anthony Barber.

long to genera moderately rich to rich in species, such as *Poratia, Chondrodesmus, Lamyctes, Cryptops*, etc. A pertinent question arises as to why often only one species succeeds in establishing populations on foreign continents, sometimes becoming quite widespread to even cosmopolitan, whereas its rather numerous congeners fail to do so. Specific adaptive ecological patterns may be an issue, but, as noticed

Figure 7.2.6. *Rhinotus purpureus* (Pocock, 1894) [Diplopoda: Polyzoniida: Siphonotidae]. Japan: Minami-Daito. Credit: Zoltán Korsós.

Figure 7.2.7. *Eurygyrus ochraceus* C.L. Koch, 1847 [Diplopoda: Callipodida: Schizopetalidae]. Ukraine: Crimea. Credit: Kiril Makarov.

above, obligate or opportunist parthenogenesis is probably a major trait favoring dispersal at least because a single founder juvenile or female is sufficient to arrive at destination and found a population. It has to be noted that the successful myriapod invaders tend to be among the smallest species, thus being more easily transported, better fitted to find a suitable microhabitat, and sometimes requiring a shorter time and even a smaller number of developmental stages to reach maturity (Golovatch 2009).

Figure 7.2.8. *Chondrodesmus* cf. *riparius* Carl, 1914 [Diplopoda: Polydesmida: Chelodesmidae]. Denmark: Copenhagen. Credit: Gert Brovad.

Figure 7.2.9. *Oxidus gracilis* (C.L. Koch, 1847) [Diplopoda: Polydesmida: Paradoxosomatidae]. Italy: Porto Badino (Borgo Hermada – Terracina). Credit: Massimiliano Di Giovanni.

Figure 7.2.10. *Paraspirobolus lucifugus* (Gervais, 1836) [Diplopoda: Spirobolida: Spirobolellidae]. Japan: Okinawa. Credit: Zoltán Korsós.

Another possible pathway of the introduction of exotic myriapods to Europe is their intentional import as 'pets', and their further escape from pet keepers. Large *Scolopendra* spp., as well as some large and colorful millipedes of the orders Spirobolida, Spirostreptida and Sphaerotheriida are quite popular pet animals subjected to trade in pet shops. Although there are many guides and internet resources available for keeping and caring for exotic species, there is no reliable information about the importance of the 'pet' trade for the introduction of alien myriapods to Europe. However, the establishment of pet myriapods in the wild is in most cases very unlikely.

7.2.6. The most invaded ecosystems and habitats

Man-made artificial environments (pastures and cultivated lands, greenhouses, urban and suburban areas) constitute the main habitat types hosting alien myriapods (Table 7.2.1). Species of tropical and subtropical origin are likely to be restricted to greenhouses or equivalent artificially warmed habitats. Some of them, in the summer season in the southern countries perhaps could survive also outdoors in close proximity to the hothouses. However, 11 species have been reported from natural habitats in Europe, where they most likely were able to establish viable populations. So far the alien species of symphylans and pauropods are unknown in natural areas, which is not the case with several species of the other two myriapod classes. The millipede *Oxidus gracilis*, which is bisexual everywhere and is naturalized in several areas in Europe and in the Caucasus, has been found in forests close to suburban and urban areas (Tömösváry 1879), in woodlands of *Robinia pseudoacacia* in the Kanev Nature Reserve, Ukraine

Figure 7.2.11. *Trigoniulus corallinus* (Gervais, 1847) [Diplopoda: Spirobolida: Trigoniulidae]. Taiwan. Credit: Zoltán Korsós.

(Chornyi and Golovatch 1993) and records from caves also exist (Strasser 1974, Vicente and Enghoff 1999). On the Canary Islands the species is quite widespread invading various, mostly dry and warm, habitats (Arndt et al. 2008). According to Palmén (1949), *O. gracilis* dies when subjected for 2 hours to a temperature of minus 4°C. This means that in North Europe the species can survive only in hothouse conditions. *Cylindroiulus truncorum* mainly inhabits synanthropic habitats: greenhouses, gardens, parks, woodpiles, school grounds, cemeteries, spoil heaps, horticultural nurseries (Kime 2004, Korsós and Enghoff 1990).

Eurygyrus ochraceus occurs in the Crimea only in a patch of semi-natural xerophytic vegetation ca. 1 km long and 100–300 m wide along a watershed. It was reported to be rather common, although not too abundant on the site and is definitely an anthropochore (Golovatch 2008).

Lamyctes emarginatus shows remarkable plasticity regarding the surrounding environment, although in the British Isles there is preponderance of rural records in comparison with (sub)urban ones. In artificial habitats it has been reported from gardens, roads, roadside verges, hedges, embankments, crops of *Zea mays* and *Medicago sativa*, even in human rubbish (Eason 1964, Minelli and Iovane 1987, Barber and Keay 1988). In natural habitats it lives in various woods (deciduous or mixed coniferous/deciduous) and has also been recorded from open and coastal areas (Barber and Keay 1988, Zerm 1997, Zapparoli 2006). According to Andersson (2006), it predominates in open and disturbed areas with sparse vegetation. A great many of these localities are associated with lake shores, river gravels or river banks. *L. emarginatus* shows clear preferences for temporarily flooded sites, no matter for how long the inundation lasts. Its appearance as a pioneer species on mine sites may indicate that the species shows preference to disturbed habitats (Zerm 1997). In close proximity to water pools the species abundance can reach 95% of all centipedes (Minoranskii 1977).

Two of the (presumed) alien geophilomorphs, *Arenophilus peregrinus* and *Nothogeophilus turki,* have been recorded in coastal areas, where they occur under stones and in soil close to rocky sea cliffs with sparse vegetation although *A. peregrinus* has been found inland in Cornwall in woodland and one of the Isle of Wight records for *Nothogeophilus turki* was from an area of demolished buildings with copious rubbish on the ground although no more than 5 m from the tidal river (A.N. Keay *pers. comm.)*.

Considerable fluctuation in the abundance of some alien species have been observed by Barber (2009b) in the tropical hothouse of the Eden Project. *P. lucifugus* which was not found in 2003/4, was rather restricted in its occurrence in 2005, had become abundant throughout by 2009. Likewise, *C. doriae* which has been relatively uncommon and limited in occurrence in 2005 was the dominant species there in 2009. Conversely, *T. javanicus*, which had been abundant in 2005, was difficult to find in 2009 (Barber 2009b).

7.2.7. Ecological and economic impact

Alien myriapods are unlikely to pose major threats to native biodiversity and ecosystems. The number of species established in the wild being very limited (12 species, *ca* 30%) for the moment (Table 7.2.1). Diplopods are detrivorous animals, consuming 10–15% of the leaf litter in temperate forest and as thus contribute significantly to soil formation processes through the fragmentation of leaves which stimulates microbial activity. They may thus indirectly influence the fluxes of nutrients (Hopkin and Read 1992). Nevertheless, some alien diplopods could be harmful to cultivated plants, especially in the artificial habitats where temperature and humidity conditions allow species establishment and expansion. Invasive soil invertebrates may also have an impact on the structure and function of natural ecosystems. They can change soil carbon, nitrogen and phosphorus pools and can considerably affect the distribution and function of roots and micro-organisms (Arndt and Perner 2008). In addition, mass occurrences and swarming, which have been observed in several countries in Europe, may have negative ecological and economic impact although the causes still remain obscure (Sahli 1996, Voigtländer 2005). An example of a plant-damaging alien myriapod is *Oxidus gracilis*, which is regarded as a pest in several European countries. This species is very common in greenhouses where its density may exceed 2500 ind./m^2. It is known for attacking vegetable and fruit crops such as sugar beet, potatoes, strawberries, cucumbers, orchard fruits, roots of wheat, and flowers in outdoor cultivated areas. Furthermore, several thousand *O. gracilis* were once found after rain in a house in Lenoir City, Tennessee, USA, with most of the city infested during the same outbreak (Hopkin and Read 1992). As a curiosity, one might also mention the report by the classical writer Theophrastus, according to whom an army of millipedes once overran Rhoeteum in the present province of Çanakkale (northwestern Turkey) and drove its human inhabitants into the sea (Sharples 1994, Enghoff and Kebapći 2008).

Several plants can withstand the attacks of symphylans but they may cause severe damage to growing crops both in fields and greenhouses (Scheller 2002). Arndt and Perner (2008) recently carried out a study on the impact of invasive ground-dwelling predatory species, including alien centipedes, in the native laurel forest habitat in the Canary Islands. They found that centipedes in laurel forests seem to be much more variable than carnivorous ground beetles since the 14 recorded species include representatives of three orders with very different characters. They tentatively recognised four functional groups of centipedes: a micro-cephalic schendylid type, (ii) a geophilid type with medium head size and extreme body length, (iii) a scolopendromorph type, and (iv) a macro-cephalic lithobiomorph type. These groups suggest patterns of invasion similar to the coleopteran predators: autochthonous and introduced species of the same size class and group are mutually exclusive (Arndt 2006).

The potential role of tropical giant millipedes and centipedes (*Scolopendra* spp.) kept as pets has been little analyzed as a source of health problems in relation to their defensive fluids or their bites which can cause pathological reactions if exposed to skin, mouth/throat or eyes (Rein 2002).

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References

Adis J, Harvey M (2000) How many Arachnida and Myriapoda are there world-wide and in Amazonia? *Studies on Neotropical Fauna and Environment* 35 (2): 139–141.

Adis J, Golovatch S, Wilck L, Hansen B (2000) On the identities of *Muyudesmus obliteratus* Kraus, 1960 versus *Poratia digitata* (Porat, 1889) with first biological obstervations on parthenogenetic and bisexual populations (Diplopoda: Polydesmida: Pyrgodesmidae). In: Wytwer J, Golovatch SI (Eds) *Progress in Studies on Myriapoda and Onychophora. Fragmenta Faunistica* Warszawa 43 (Supplement): 149–170 (for 1999).

Akkari N, Stoev P, Lewis JGE (2008) The scolopendromorph centipedes (Chilopoda, Scolopendromorpha) of Tunisia: taxonomy, distribution and habitats. *ZooKeys* 3: doi: 10.3897/zookeys.3.51

Akkari N, Stoev P, Enghoff H, Nouira S (2009) The millipede order Julida (Myriapoda: Diplopoda) in Tunisia, with an overview of the North African species. *Soil Organisms* 81 (3): 453–488.

Andersson G (1984) Post-embryonic development of *Lamyctes fulvicornis* Meinert. *Entomologica Scandinavica* 15: 9–14.

Andersson G (2006) Habitat preferences and seasonal distribution of developmental stadia in *Lamyctes emarginatus* (Newport, 1844) (*L. fulvicornis* Meinert, 1868) and comparison with some *Lithobius* species (Chilopoda, Lithobiomorpha). *Norwegian Journal of Entomology* 53 (2): 311–320.

Andersson G, Enghoff H (2007) Nyinförd mångfoting – palmbladfoting *Chondrodesmus* cf. *riparius*. *Fauna och Flora* 102 (4): 2–5.

Andersson G, Meidell B, Scheller U, Winqvist J-Å, Osterkamp-Madsen M, Djursvoll P, Budd G, Gårdenfors U (2005) Nationalnyckeln till Sveriges flora och fauna. Månfotingar. Myriapoda. Uppsala: Art Databanken, SLU. 351 pp.

Arndt E (2006) Niche occupation by invasive ground-dwelling predator species in Canarian laurel forests. *Biological Invasions* 8: 893–902.

Arndt E, Perner J (2008) Invasion patterns of ground-dwelling arthropods in Canarian laurel forests. *Acta Oecologica* 34: 202–213.

Arndt E, Enghoff H, Spelda J (2008) Millipedes (Diplopoda) of the Canarian Islands: Checklist and key. *Biological Invasions* 8: 893–902.

Attems C (1935) Myriopoden von Epirus. *Zoologischer Anzeiger* 110 (5–6): 141–153.

Baéz M, Oromí P (2004) Symphyla, Pauropoda. In: Izquierdo I, Martín JL, Zurita N, Arechavaleta M (Eds) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). Consejeria de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias, p. 177.

Barber AD (1995) *Lithobius lucifugus* L. Koch (Chilopoda, Lithobiomorpha), a centipede new to the British Isles from Scotland. *Bulletin of the British Myriapod Group* 11: 63–65.

Barber AD (2008) Key to the identification of British centipedes. Shrewsbury: FSC Publications. 96 pp.

Barber AD (2009a) Centipedes. *Synopses of the British Fauna (New Series)*. Shrewsbury: Field Studies Council, FSC Publications. 228 pp.

Barber T (2009b) Centipedes, millipedes and woodlice in the Eden project. *Bulletin of the Peninsular Invertebrate Forum* 19: 1–4.

Barber AD, Eason EH (1986) A redescription of *Lithobius peregrinus* Latzel, new record, a centipede new to Britain (UK) (Chilopoda Lithobiomorpha). *Journal of Natural History* 20: 431–438.

Barber T, Gregory S, Read H (2010) Field Meeting Reports: Ladock, Cornwall: combined report. *Bulletin of the British Myriapod & Isopod Group* 24: 65–74.

Barber AD, Keay AN (1988) Provisional atlas of the centipedes of the British Isles. Biological Records Centre, Natural Environment Research Council, Institute of Terrestrial Ecology; Monks Wood Experimental Station Huntington. 127 pp.

BBC News: Giant centipede legs it to the UK. http://news.bbc.co.uk/go/em/fr/-/1/hi/england/london/4201634.stm [accessed 31 August 2005].

Bergersen R, Olsen KM, Djursvoll P, Nilssen AC (2006) Centipedes (Chilopoda) and millipedes (Diplopoda) in North Norway. *Norwegian Journal of Entomology* 53: 23–38.

Blower JG (1985) Millipedes. Keys and notes for the identification of the species. *Synopses of the British Fauna* 35: 1–242.

Blower JG, Rundle AJ (1980) *Prosopodesmus panporus*, an interesting new species of polydesmoid millipede from the Royal Botanic Gardens, Kew, England. *Myriapodologica* 1 (4): 27–34.

Blower JG, Rundle AJ (1986) *Poratia digitata*, a new British hothouse millipede. *Bulletin of the British Myriapod Group* 3: 11–16.

Bocher J, Enghoff H (1984) A centipede in Groenland: *Lamyctes fulvicornis* Meinert, 1868 (Chilopoda, Lithobiomorpha, Henicopidae). *Entomologiske Meddelelser* 52: 49–50.

Bonato L, Capul-Magaña F, Minelli A (2009) *Mecistocephalus guildingii* Newport, 1843, a tropical centipede with amphi-Atlantic distribution (Chilopoda: Geophilomorpha). *Zootaxa* 2271: 27–42.

Borges PAV (2008a) Symphyla, Pauropoda. In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Direcção Regional do Ambiente and Universidade dos Açores, Horta, Hangra do Heroísmo an Ponta Delgada, p. 183.

Borges PAV (2008b) Symphyla, Pauropoda. In: Borges PAV, Abreu C, Aguiar AMF, Carvalho P, Jardim R, Melo I, Oliveira P, Sérgio C, Serrano ARM, Vieira P (Eds) A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens Archipelagos. Direcçao Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Anga do Heroísmo, pp. 288–289.

Borges PAV, Enghoff H (2005) Chilopoda. In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Direcção Regional do Ambiente and Universidade dos Açores, Horta, Hangra do Heroísmo an Ponta Delgada, p. 184.

Brölemann H (1889) Contributions à la faune myriapodologique méditerranéenne. *Annales de la Société Linnéenne de Lyon* 35: 273–285.

Brolemann HW (1930) Eléments d'une faune des myriapodes de France. Chilopodes. *Faune de France* 25. Toulouse: Imprimerie Toulousaine; Paris: P. Lechevalier. 405 pp.

Carl J (1914) Die Diplopoden von Columbien nebst Beiträgen zur Morphologie der Stemmatoiuliden. *Mémoires de la Société neuchâteloise des Sciences naturelles* 5: 821–993.

Ceuca T (1974) Noi contributii la cunoaşterea diplopodelor din fauna României. *Studia Universitatis Babeş-Bolyai, Seria Biologia* 19: 91–97.

Chornyi NG, Golovatch SI (1993) Dvuparnonogie mnogonozhky ravninnych territorij Ukrainy. [Millipedes (Diplopoda) of the plain areas of the Ukraine]. Kiev: Kiev University. 56 pp.

Christian E (1996) Die Erdlaufer (Chilopoda: Geophilida) des Wiener Stadtgebietes. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Österreich* 133: 107–132.

Christian E, Szeptycki A (2004) Tausendfüβer und Bodeninsekten aus dem Botanischen Gartens der Universität Wien. In: Pernstich A, Krenn HW (Eds) Die Tierwelt des Botanischen

Gartens der Universität Wien. Wien: Eigenverlag Institut für Angewandte Biologie und Umweltbildung, 53–64.

Clarke WJ (1938) Dispersal species by commerce. (*S. subspinipes*). *Naturalist*, London, p. 136.

Condé B (1961) Diplopodes Pénicillates des Açores et de Madère. *Boletim do Museu Municipal do Funchal* 14 (43): 7–10.

DAISIE (2009) Introduction to the List of Alien Taxa. In: Handbook of Alien Species in Europe, DAISIE, Springer Science + Business Media B.V., 133–263.

Eason EH (1964) Centipedes of the British Isles. New York: Frederick Warne. 294 pp.

Eason EH (1970) The Chilopoda and Diplopoda of Iceland. *Entomologica Scandinavica* 1: 47–54.

Eason EH, Enghoff H (1992) The lithobiomorph centipedes of the Canary Islands (Chilopoda). *Entomologica Scandinavica* 23 (1): 1–9.

Edgecombe G (2003) A new species of the Gondwanan centipede *Anopsobius* (Chilopoda: Lithobiomorpha) from New South Wales, Australia. *Zootaxa* 204: 1–15.

Edgecombe G, Giribet G (2007) Evolutionary biology of centipedes (Myriapoda: Chilopoda). *Annual Review of Entomology* 52: doi:10.1146/annurev.ento.52.110405.091326.

Enghoff H (1975a) Notes on *Lamyctes coeculus* (Brölemann), a cosmopolitic, parthenogenetic centipede (Chilopoda: Henicopidae). *Entomologia Scandinavica* 6: 45–46.

Enghoff H (1975b) *Paraspirobolus dictyonotus* (Latzel, 1895) et vaeksthustusindben nyt for Danmark (Diplopoda, Spirobolida, Spirobolellidae). *Entomologiske Meddelester* 43: 17–20.

Enghoff H (1978) *Cylindrodesmus laniger* Schubart, a widespread, probably parthenogenetic millipede (Diplopoda, Polydesmida: Haplodesmidae). *Entomologia Scandinavica* 9: 80.

Enghoff H (1987) *Amphitomeus attemsi* (Schubart, 1934) endnu et væksthustusindben nyt for Danmark (Diplopoda, Polydesmida, Oniscodesmidae). *Entomologiske Meddelester* 54: 147–148.

Enghoff H (2001) *Benoitolus flavicollis* Mauries, 1980, another tropical tramp millipede, and notes on *Pseudospirobolellus avernus* (Butler, 1876) (Diplopoda, Spirobolida, Pseudospirobolellidae). *Entomologist's Monthly Magazine* 137 (1644–1647): 167–170.

Enghoff H (2008a) A large Neotropical millipede in European flower pots. *Bulletin of the British Myriapod and Isopod Group* 23: 38–39.

Enghoff H (2008b) Chilopoda, Diplopoda. In: Borges PAV, Abreu C, Aguiar AMF, Carvalho P, Jardim R, Melo I, Oliveira P, Sérgio C, Serrano ARM, Vieira P (Eds) A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens Archipelagos. Direcçao Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Anga do Heroísmo, pp. 289–291.

Enghoff H (2009) Myriapoda. In: Fauna Europaea. http://www.faunaeur.org/statistics.php [accessed January 2010].

Enghoff H, Borges PAV (2005) Diplopoda. In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Direcção Regional do Ambiente and Universidade dos Açores, Horta, Hangra do Heroísmo an Ponta Delgada, p. 184.

Enghoff H, Kebapći Ü (2008) *Calyptophyllum longiventre* (Verhoeff, 1941) invading houses in Turkey, with the first description of the male (Diplopoda: Julida: Julidae). *Journal of Natural History* 42: 2143–2150.

Enghoff H, Golovatch S, Nguyen Duc A (2004) A review of the millipede fauna of Vietnam (Diplopoda). *Arthropoda Selecta* 13 (1–2): 29–43.

Evans W (1900) Scottish Myriapoda. *The annals of Scottish natural history* 1900: 127.

Farzalieva G, Zalesskaja N, Edgecombe G (2004) A new genus and species of lithobiomorph centipede (Chilopoda: Lithobiomorpha: Anopsobiidae) from eastern Kazakhstan. *Arthropoda Selecta* 13 (4): 219–224.

Gervais P (1836) Sur l'Iulus lucifugus. *Annales de la Société entomologique de France*, Sér. 1, 5: 56–57.

Gervais P (1837) Études pour servir à l'histoire naturelle des Myriapodes. *Annales des Sciences naturelles, Zoologie* (2e série), 7: 35–60, Pl. IV.

Gibson-Carmichael TD (1883) *Scutigera coleoptrata* near Aberdeen. *Entomological Monthly Magazine* 20: 88.

Golovatch SI (2008) On three remarkable millipedes (Diplopoda) from the Crimea, Ukraine. *International Journal of Myriapodology* 1: doi: 10.1163/187525408X316767.

Golovatch SI (2009) Millipedes (Diplopoda) in extreme environments. In: *Species and Communities in Extreme Environments. Festschrift towards the 75th Anniversary and a Laudatio in Honour of Academician Yuri Ivanovich Chernov*. Sofia-Moscow: Pensoft & KMK Sci. Press, 87–112.

Golovatch SI, Sierwald P (2001) Review of the millipede genus *Poratia* Cook & Cook, 1894 (Diplopoda: Polydesmida: Pyrgodesmidae). *Arthropoda Selecta* 9 (3): 181–192.

Golovatch S, Stoev P (2010) New or poorly-known millipedes (Diplopoda) from Papua New Guinea, 1. *Arthropoda Selecta* 18 (3–4): 125–130. (for 2009)

Golovatch SI, Knapinski S, Adis J (2002) On the identity of the European hothouse millipede *Amphitomeus attemsi* (Schubart, 1934), with first biological observations of this parthenogenetic species (Diplopoda: Polydesmida: Oniscodesmidae). *Arthropoda Selecta* 10 (2): 137–146.

Golovatch SI, Hoffman R, Knapinski S, Adis J (2001) Review of the millipede genus *Cylindrodesmus* Pocock, 1889 (Diplopoda: Polydesmida: Haplodesmidae). *Fragmenta faunistica* 44: 179–201.

Golovatch SI, Gruber J, Adis J, Knapinski S, Zerm M, Hansen B (2000) Parthenogenetic populations of the millipede *Cylindrodesmus laniger* Schubart, 1945 to be recorded in Europe for the first time (Diplopoda: Polydesmida, Haplodesmidae). *Arthropoda Selecta* 9 (3): 193–198.

Golovatch SI, Geoffroy J-J, Mauriès J-P, Van den Spiegel D (2009) Review of the millipede family Haplodesmidae, with descriptions of some new or poorly-known species (Diplopoda, Polydesmida). In: Golovatch SI, Mesibov R (Eds) *Advances in the Systematics of Diplopoda* I. *ZooKeys* 7: doi:10.3897/zookeys.7.117.

Gregory SJ, Jones RE (1999) *Arenophilus peregrinus* Jones, 1989 in Cornwall: a centipede new to mainland Britain. *Bulletin of the British Myriapod and Isopod Group* 15: 28–29.

Gruber J (2002) Tausendfüßer: Doppelfüßer (Myriapoda: Diplopoda). In: Neobiota in Österreich – Tiere. Wien: Umweltbundesamt GmbH, 296–301.

Gruber J, Christian E (2002) Tausendfüßer: Hundertfüßer (Myriapoda: Chilopoda). In: Neobiota in Österreich – Tiere. Wien: Umweltbundesamt GmbH, 292–296.

Hoffman R (1999) Checklist of the Millipeds of North and Middle America. *Virginia Museum of Natural History*. Special Publication 8: 1–584.

Hoffman R, Payne J (1969) Diplopods as carnivors. *Ecology* 50 (6): doi: 10.2307/1936905.

Hollington L, Edgecombe G (2004) Two new species of the henicopid centipede *Henicops* (Chilopoda: Lithobiomorpha) from Queensland and Victoria, with revision of species from Western Australia and a synoptic classification of Henicopidae. *Records of the Australian Museum* 56: 1–28. http://publications.australianmuseum.net.au/record.cfm?ref=1392.

Hopkin S, Read H (1992) The biology of millipedes. Oxford University Press. 233 pp.

Jeekel CAW (1963) Diplopoda of Guiana. *Studies on the Fauna of Suriname and other Guyanas* 11: 1–157.

Jeekel CAW (1977) Voorlopige atlas van de verspreiding der Nederlandse duizendpoten (Chilopoda). *Verslagen en Technische gegevens Instituut voor Taxonomische Zoölogie* 13: 1–55.

Jeekel CAW (2001) *Julus lucifugus* Gervais, 1836, a long overlooked name for a wide-spread synanthrope millipede (Diplopoda, Spirobolida, Spirobolellidae). *Myriapod Memoranda* 3: 39–43.

Jones RE (1989) On a new species of centipede (Chilopoda Geophilomorpha) from the Isles of Scilly. *Journal of Natural History* 23: 627–633.

Kime D (2004) The Belgian millipede fauna (Diplopoda). *Bulletin de l'institut royal des sciences naturelles de Belgique, Entomologie* 74: 35–68.

Kime D, Golovatch S (2000) Trends in the ecological strategies and evolution of millipedes (Diplopoda). *Biological Journal of the Linnean Society* 69: doi: 10.1111/j.1095-8312.2000.tb01209.x.

Kinzelbach R, Geiter O, Homma S (2001) Bestandsaufnahme und Bewertung von Neozoen in Deutschland. Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potentiellen Effekten gentechnisch veränderter Organismen. Berlin: Umweltbundesamt (Federal Environmental Agency). 52 pp.

Korsós Z, Enghoff H (1990) The *Cylindroiulus truncorum*-group (Diplopoda: Julidae). *Entomologica Scandinavica* 21: 345–360.

Korsós Z, Hornung E, Szlávecz K, Kontschán J (2002) Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. *Annales historico-naturales Musei nationalis hungarici* 94: 193–208.

Latzel R (1884) Die Myriapoden der Österreichisch-Ungarischen Monarchie. 2. Bd.: Die Symphylen, Pauropoden und Diplopoden. Wien: Alfred Hölder. 414 pp., 16 Taf., 209 Figure http://www.biologie.uni-ulm.de/cgi-in/query_all/litdetails.pl?sort=taxa&sid=T&thumb=no&lang=d&id=17915&B3=Daten+anzeigen.

Latzel R (1895) Die Myriopoden aus der Umgebung Hamburgs. *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten*, Beiheft 12: 99–109.

Lee P (2006) Atlas of the Millipedes (Diplopoda) of Britain and Ireland. Sofia-Moscow: Pensoft, Series Faunistica 59. 216 pp.

Lewis JGE (1981) The biology of centipedes. New York: Cambridge University Press. 476 pp.

Lewis JGE (1988) *Scolopendra subspinipes subspinipes* Leach in a cargo of bananas. *Bulletin of the British Myriapod Group*, Miscellanea 5: 36.

Lewis JGE (2007) On *Cryptops doriae* Pocock, from the wet tropical biome of the Eden project, Cornwall (Chilopoda, Scolopendromorpha, Cryptopidae). *Bulletin of the British Myriapod and Isopod Group* 22: 12–16.

Lewis JGE, Rundle AJ (1988) *Tyggarup javanicus* (Attems), a geophilomorph centipede new to the British Isles. *Bulletin of the British Myriapod Group* 5: 3–5.

Lewis JGE, Jones RE, Keay AN (1988) On a new genus and species of centipede (Chilopoda Geophilomorpha Chilenophilidae) from the British Isles. *Journal of Natural History* 22: 1657–1663.

Manfredi P (1930) Di una grossa scolopendra catturata nei dintorni di Milano. *Natura*, Milano 21: 219–220.

Marek P, Bond J (2006) Biodiversity hotspots: Rediscovery of the world's leggiest animal. *Nature* 2006, 441(7094): 707: doi:10.1038/441707a

Meinert F (1868) Danmarks scolopender og lithobier. *Naturistorisk Tidsskrift* (3) 5: 241–268.

Minelli A (1991) I Chilopodi dell'Italia nord-orientale (Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia) (Chilopoda). *Gortania - Atti del Museo Friulano di Storia Naturale* 13: 157–193.

Minelli A (2006) CHILOBASE. A web resource for Chilopoda taxonomy. http://chilobase.bio.unipd.it. [accessed January 2010].

Minelli A, Golovatch SI (2001) Myriapods. In: Levin SA (Ed) Encyclopedia of biodiversity. San Diego: Academic Press 4: doi:10.1016/B0-12-226865-2/00204-2.

Minelli A, Iovane E (1987) Habitat preferences and taxocenoses of Italian centipedes (Chilopoda). *Bollettino del Museo civico di Storia naturale di Venezia* 37: 7–34.

Minoranskii VA (1977) [Some data on (Chilopoda Myriapoda) from the Rostov Oblast]. *Vestnik Zoologii* 4: 38–43.

Negrea S (1989) Sur la présence de *Lamyctes fulvicornis* Meinert, 1868 (Chilopoda Henicopidae) en Roumanie. *Miscellanea Speologica Romanica* 1: 169–174.

Palmén E (1948) The Chilopoda of Eastern Fennoscandia. *Annales zoologici Societatis zoologico-botanicae fennicae Vanamo* 13 (4): 1–45.

Palmén E (1949) The Diplopoda of Eastern Fennoscandia. *Annales zoologici Societatis zoologico-botanicae fennicae Vanamo* 13 (6): 1–53.

Palmén E (1952) Survey of the Diplopoda of Newfoundland. *Annales zoologici Societatis zoologico-botanicae fennicae Vanamo* 15 (1): 1–31.

Pocock RI (1902) Myriapoda. *The Victoria History of the County of Surrey* 1: 176–178. http://www.archive.org/stream/historyofsurrey01malduoft#page/176/mode/2up.

Pocock RI (1906) Antennata: Myriapoda. In: The wild fauna and flora of the Royal Botanic Gardens, Kew. Royal Botanic Gardens, Kew. *Bulletin of Miscellaneous Information*, Additional Series 5: 21–22.

Read H (2008) Records of millipedes from Kew Gardens and the Eden project, including descriptions of three species. *Bulletin of the British Myriapod and Isopod Group* 23: 27–35.

Rein JO (2002) Exotic invertebrates as pets in Norway – a health problem? *Tidsskrift for den Norske Legeforening* 30, 122: 2896–2901 [in Norwegian].

Roques A, Rabitsch W, Rasplus J-Y, Lopez-Vaamonde C, Nentwig W, Kenis M (2009). Alien terrestrial invertebrates of Europe. In: Handbook of Alien Species in Europe, DAISIE, Springer Science + Business Media B.V., 63–79.

Sahli F (1996) Déplacements en masse dans le sud-est de la France chez *Ommatoiulus sabulosus* (Myriapoda, Diplopoda, Julidae) avec invasions d'habitations. In: *Acta Myriapodologica*. *Mémoires du Muséum National d'Histoire Naturelle* 169: 587–598.

Scheller U (2002) A new species of *Hanseniella* Bagnal (Myriapoda, Symphyla) found in hothouse. *Mitteilungen aus dem Museum für Naturkunde in Berlin*, *Zoologische Reihe* 78 (2): 269–273.

Schubart O (1925) Die Diplopodenfauna Schleswig-Holsteins. *Zoologische Jahrbücher, Abteilung für Systematik, Ökologie und Geographie der Tiere* 49: 537–610.

Schubart O (1934) Tausendfüßler oder Myriapoda. I: Diplopoda. *Die Tierwelt Deutschlands und der angrenzenden Meeresteile* 28: 1–318.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53, 4: 151–170.

Sharples RW (1994) Theophrastus of Eresus. Sources for his life, writings, thought and influence. Vol. 5. *Sources on Biology*. Leiden (Netherlands): Brill. 273 pp.

Shear W, Peck S (1992) Centipeds (Chilopoda) and Symphyla of the Galápagos Islands, Ecuador. *Canadian Journal of Zoology* 70 (11): 2260–2274.

Shelley RM (1998) Occurrence of the milliped *Glyphiulus granulatus* (Gervais) in the Hawaiian Islands (Spirostreptida: Cambalidea: Cambalopsidae). Bishop Museum Occasional Papers 56: 36–37.

Shelley RM, Lehtinen PT (1999) Diagnoses, synonymies and occurrences of the pantropical millipeds, *Leptogoniulus sorornus* (Butler) and *Trigoniulus corallinus* (Gervais) (Spirobolida: Pachybolidae: Trigoniulinae). *Journal of Natural History* 33: doi: 10.1080/002229399299932

Silvestri F (1933) Nuovi contributi alla conoscenza della fauna delle isole italiane dell'Egeo. I. Descrizione di un nuovo genere di chilopodo henicopino. *Bollettino del Laboratorio di Zoologia Generale e Agraria della Regia Scuola Superiore d'agricoltura*, Portici 27: 57–60.

Stoev P (2004) Myriapoda (Chilopoda, Diplopoda) in Urban Environments in the City of Sofia. In: Penev L, Niemelä J, Kotze DJ, Chipev N (Eds) *Ecology of the City of Sofia. Species and communities in an Urban Environment*. Sofia-Moscow: Pensoft Publishers, 299–306.

Stoev P (2007) Myriapoda of Bulgaria. In: Fet V, Popov A (Eds) *Monographiae Biologicae. Biogeography and Ecology of Bulgaria*. Dodrecht: Springer Publishers, 379–403.

Strasser C (1974) I diplopodi chilognati della Sardegna. *Fragmenta Entomologica* 10: 231–293.

Tabacaru I, Giurginca A, Vanoaica L (2003) Cavernicolous Diplopoda of Romania. *Travaux de l'Institut de Spéologie "Emile Racovitza"* 41–42: 121–148.

Tömösváry Ö (1879) Néhány hazánkban előforduló Myriopodáról. *Orvos- Természettudományi Értesitő*, Kolozsvár 3: 22–25.

Verhoeff KW (1926) Über einige von Dr. I. Buresch in Bulgarien gesammelte Diplopoden. 2. Aufsatz. *Bulletin de la Société Entomologique de Bulgarie* 3: 193–210.

Verhoeff KW (1933) Symphyla (Bronn's Klassen und Ordungen Tierreiches 5(2), 3, 1). Leipzig: de Gruyter, 1–120.

Verhoeff KW (1934) Pauropoda (Bronn's Klassen und Ordungen des Tierreiches 5(2), 3, 2). Leipzig: de Gruyter, 121–200.

Vicente M, Enghoff H (1999) The millipedes of the Canary Islands. *Vieraea* 27: 183–204.

Voigtländer K (2005) Mass occurrences and swarming behaviour of millipedes (Diplopoda: Julida) in Eastern Germany. *Peckiana* 4: 181–188.

Wittenberg R (Ed) (2005) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. CABI Bioscience Switzerland Centre report to the Swiss Agency for Environment, Forests and Landscape. 417 pp.

Zapparoli M (1989) I Chilopodi delle Alpi sud-orientali. *Biogeographia, Lavori della Società Italiana di Biogeografia, N.S.* 12 (1987): 553–585.

Zapparoli M (1999) The present knowledge of the centipede fauna of Anatolia (Chilopoda). *Biogeographia, Lavori della Società Italiana di Biogeografia*, N. S. 20: 105–177.

Zapparoli M (2002) A catalogue of the centipedes of Greece (Chilopoda). *Fragmenta Entomologica* 34: 1–146.

Zapparoli M (2006) A catalogue of the centipedes (Chilopoda) of Central Apennines (Italy). *Bollettino del Museo civico di Storia naturale di Verona*, Botanica, Zoologia 30: 165–273.

Zapparoli M, Oromi P (2004) Chilopoda. In: Izquierdo I, Martin JL, Zurita N, Archavaleta M (Eds) *Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres)*. Consejeria de Politica Territorial y Medio Ambiente Gobierno de Canarias, 179–180.

Zapparoli M, Minelli A (1993) Tassonomia, corologia, ecologia delle specie del genere *Pleurolithobius* Verhoeff, 1909 (Chilopoda, Lithobiomorpha). *Bollettino del Museo Regionale di Scienze Naturali di Torino* 11: 331–345.

Zapparoli M, Minelli A (2005) Chilopoda. In: Ruffo S, Stoch F (Eds) Checklist and distribution of the Italian fauna. *Memorie del Museo Civico di Storia naturale di Verona* 2. Serie, sezione Scienze della Vita 17: 123–125, with data on CD-ROM.

Zerm M (1997) Distribution and phenology of *Lamyctes fulvicornis* and other lithobiomorph centipedes in the floodplain of the Lower Oder Valley, Germany (Chilopoda, Henicopidae: Lithobiidae). *Entomologica Scandinavica*, Supplement 51: 125–132.

Table 7.2.1. List and main characteristics of the myriapod species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Only selected references are given. Last update 10/03/2010.

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Pauropoda								
Tetramerocerata								
	Pauropodidae	*Allopauropus pseudomillotianus* Remy & Balland, 1958	A	Southeast Asia (India, Sri Lanka)	1958, FR	FR, NO	J100	Andersson et al. (2005)
Symphyla								
Symphylomorpha								
	Scutigerellidae	*Hanseniella caldaria* (Hansen, 1903)	A	Tropical, subtropical (North America up to Mexico, South America, sub-Saharan Africa, Sri Lanka, Galapagos Islands, and possibly New Zealand)	1903, DK	DK, FR, GB, MC, NO	J100	Andersson et al. (2005), Scheller (2002), Shear and Peck (1992)
		Hanseniella oligomacrochaeta Scheller, 2002	C	Unknown. Tropical, subtropical?	2000, DE	DE	J100	Scheller (2002)
		Hanseniella orientalis (Hansen, 1903)	A	Tropical, subtropical (South and southeastern Asia, Central and South America, islands in the Pacific)	2000, DE	DE	J100	Scheller (2002)
Chilopoda								
Geophilomorpha								
	Mecistocephalidae	*Mecistocephalus guildingii* Newport, 1843	A	Amphi-Atlantic (coasts of Tropical America, African coast from Gambia to Liberia, Atlantic islands)	1895, DE	DE, FR, GB, PT-MAD	J100	Bonato et al. (2009), Pocock (1906)
		Mecistocephalus maxillaris (Gervais, 1837)	C	Unknown, tropical?	1837, FR	DK, FR, NL	J100	Andersson et al. (2005), Bonato et al. (2009), Jeekel (1977)
		Tygarrup javanicus Atems, 1929	A	Southeast Asia (Java, Vietnam, Cambodia), The Seychelles	1975, GB	AT, GB	J100	Barber (2009b), Christian (1996), Lewis and Rundle (1988)

Class ***Order***	**Family**	**Species**	**Status**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**References**
	Geophilidae	*Arenophilus peregrinus* Jones, 1989	C	Unknown, genus present in North America	1986, GB	GB	B3, I2	Barber (2009a), Gregory and Jones (1999), Jones (1989)
		Nothogeophilus turki Lewis, Jones & Keay, 1988	C	Unknown	1985, GB	GB	B3	Barber (2009a), Lewis et al. (1988)
	Oryidae	*Orphnaeus brevilabiatus* (Newport, 1845)	A	Tropical, subtropical (Australia, Central and South America, Sub-Saharan Africa, Madagascar, East Asia, Arabian Peninsula, Hawaii)	19th century, SE	SE	Unknown, J100?	Andersson et al. (2005)
	Schendylidae	*Nyctunguis persimilis* Attems, 1932	C	Unknown. Genus present in North America	1996, AT	AT	I2?	Christian (1996), Christian and Szeptycki (2004), Gruber and Christian (2002)
Chilopoda ***Scolopendromorpha***								
	Cryptopidae	*Cryptops doriae* Pocock, 1891	A	Southeast Asia, Papua New Guinea, The Seychelles	2007, GB	GB	J100	Barber (2009a), Lewis (2007)
	Scolopendridae	*Scolopendra gigantea* Linnaeus, 1758	A	Central and South America	2005, GB	GB	J1	BBC News (2005)
		Scolopendra morsitans Linnaeus, 1758	A	Tropical, subtropical. North and South America, Atlantic Ocean Islands, Europe, Africa, Arabian Peninsula, Southeast Asia, Indian Ocean Islands, Australia, New Zealand, Pacific Islands	1902, GB	GB	J100	Akkari et al. (2008), Pocock (1906)
		Scolopendra subspinipes Leach, 1815	A	East and South Asia	1902, GB	GB	J100	Minelli (2006), Pocock (1906)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Chilopoda								
Lithobiomorpha								
	Henicopidae	*Ghilaroviella* cf. *valiachmedovi* Zalesskaja, 1975	A	Unknown. *G. valiachmedovi* occurs in Central Asia (Tajikistan)	2004, AT	AT	I2	Christian and Szeptycki (2004)
		Lamyctes (*Metalamyctes*) *albipes* (Pocock, 1895)	C	Southeast Asia (Java), Sakhalin Island, Guadeloupe, The Seychelles	1988, ES-CAN	ES-CAN	H3, H5	Eason and Enghoff (1992), Hollington and Edgecombe (2004)
		Lamyctes (*Lamyctes*) *coeculus* (Brölemann, 1889)	A	Tropical, subtropical. Known from Australia, Central and South America, Sub-Saharan Africa, Madagascar	1889, IT	DK, ES-CAN, FI, FR, GB, IT, SE	J100, J	Barber (2009a), Enghoff (1975a), Zapparoli and Minelli (2005)
		Lamyctes (*Lamyctes*) *emarginatus* (Newport, 1844)	A	Australasia (Australia+ New Zealand) is the possible areas of origin. Known also from North and South America, Africa, Asia Minor, Greenland, Iceland, New Caledonia, islands in the Pacific	1868, DK	AT, BE, BG, CZ, DE, DK, ES-CAN, FI, FR, GB, GL, GR, HU, IT, LU, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, SK, UA	B1, D, E, F4, F9, G1, G3, J1, J2, J3, J4, J5, J6, I, I1, I2, X6, X7, X23	Barber and Keay (1988), Bocher and Enghoff (1984), Meinert (1868), Minelli and Iovane (1987), Negrea (1989), Palmén (1948, 1952), Zapparoli and Minelli (2005)
		Rhodobius lagoi Silvestri, 1933	C	Unknown, possibly tropical, subtropical. Subfamily Anapsobiinae distributed in South America, South Africa, Australia, Japan, Vietnam, Kazakhstan and Tajikistan	1933, GR-SEG	GR-SEG (Rhodes)	I ?	Silvestri (1933), Zapparoli (2002)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Diplopoda ***Polyxenida***								
	Polyxenidae	*Polyxenus fasciculatus* Say, 1821	A	Nearctic (USA), Bermuda Islands	1961, PT-MAD	ES-CAN, PT-MAD	G	Attems (1935), Condé (1961), Vicente and Enghoff (1999)
Diplopoda ***Polyzoniida***								
	Siphonotidae	*Rhinotus purpureus* (Pocock, 1894)	A	Tropical, subtropical (South and Central America, islands in Indian and Pacific oceans)	1986, GB	GB	J100	Barber (2010), Read (2008)
Diplopoda ***Callipodida***								
	Schizopetalidae	*Eurygyrus ochraceus* C.L. Koch, 1847	A	Asia (Turkey)	1925, BG	BG, UA	E1, I2	Golovatch (2008), Stoev (2007), Verhoeff (1926)
Diplopoda ***Polydesmida***								
	Chelodesmidae	*Chondrodesmus* cf. *riparius* Carl, 1914	A	South America	2000, SE	DE, DK, NO, SE	J	Andersson and Enghoff (2007), Enghoff (2008a)
	Haplodesmidae	*Cylindrodesmus hirsutus* Pocock, 1889	A	Tropical, subtropical (South America, Southeast Asia, Papua New Guinea, islands in Indian and Pacific oceans)	1950-1985	AT, DE, FR, GB, HU, SK	J100	Golovatch and Stoev (2010), Golovatch et al. (2001), Golovatch et al. (2009), Read (2008)
		Prosopodesmus panporus Blower & Rundle, 1980	A	Unknown, other species in the genus pantropical	1975, GB	GB	J100	Blower and Rundle (1980), Golovatch et al. (2009), Read (2008)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
	Oniscodesmidae	*Amphitomeus attemsi* (Schubart, 1934)	A	South America (Venezuela or Colombia)	1930, DE	AT, CH, DE, DK, GB, HU, NL, PL, SK	J100	Barber and Eason (1986), Enghoff (1987), Enghoff (2009), Golovatch et al. (2002), Gruber (2002), Korsós et al. (2002)
	Paradoxosomatidae	*Asiomorpha coarctata* (De Saussure, 1860)	A	Southeast Asia	1906, GB	GB	J100	Pocock (1906)
		Chondromorpha kelaarti (Humbert, 1865)	A	India, Sri Lanka	1902, GB	GB	J100	Pocock (1906)
		Oxidus gracilis (C.L. Koch, 1847)	A	Asia (East or Southeast)	1879, HU	AT, BE, BG, BY, CH, CZ, DE, DK, ES, ES-BAL, ES-CAN, FI, FR, GB, HU, IE, IS, IT, LT, LU, LV, MC, MD, MK, MT, NL, NO, PL, PT-MAD, PT-AZO, RO, RU, SE, SI, SK, UA	J, J100, G	Blower (1985), Enghoff (2009), Enghoff et al. (2004), Evans (1900), Hoffman (1999), Pocock (1902), Read (2008), Šefrová and Laštůvka (2005), Stoev (2004)
	Pyrgodesmidae	*Cynedesmus formicola* (Cook, 1896)	C	Unknown, genus native of Central America	1896, ES-CAN	ES-CAN, HU, PT-MAD	J100	Attems (1935), Korsós et al. (2002), Vicente and Enghoff (1999)
		Poratia digitata (Porat, 1889)	A	Tropical and subtropical (Southern North and Central America)	1889, SE	AT, CH, DE, DK, FR, GB, NL, NO, SE	J100	Blower and Rundle (1986), Golovatch and Sierwald (2001), Gruber (2002), Latzel (1895)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
		Poratia obliterata (Kraus, 1960)	A	Tropical (South and Central America: Peru, Colombia, Brazil, Costa Rica)	late 1990s, DE	DE, FR, HU	J100	Adis et al. (2000), Golovatch and Sierwald (2001), Korsós et al. (2002)
	Trichopolydesmidae	*Napocodesmus endogeus* Ceuca, 1974	C	Unknown, only female/s known; the second tentative congener occurs in Romania and Moldova	1969, RO	RO	I2?	Ceuca (1974), Tabacaru et al. (2003)
Diplopoda ***Julida***								
	Julidae	*Cylindroiulus truncorum* (Silvestri, 1896)	A	North Africa (Algeria, Tunisia)	1925, DE	AT, BE, CH, DE, DK, ES-CAN, FI, FR, GB, HU, LT, LU, NL, NO, PL, PT, PT-MAD, RO, SE, UA	J, J100, I2	Enghoff (2009), Kime (2004), Korsós and Enghoff (1990), Read (2008), Schubart (1925)
Diplopoda ***Spirobolida***								
	Pseudospiro-bolellidae	*Pseudospirobolellus avernus* (Butler, 1876)	A	Tropical (Southeast Asia, islands in Indian and Pacific oceans, and Caribbean Sea)	2009, GB	GB	J100	Barber et al. (2010), Enghoff (2001)
	Rhinocricidae	*Anadenobolus monilicornis* (Porat, 1876)	A	Caribbean region	1906, GB	GB	J100	Hoffman (1999), Pocock (1906)
		Anadenobolus vincenti (Pocock, 1894)	A	Saint Vincent Island, Lesser Antilles	1900, GB	GB	J100	Hoffman (1999), Pocock (1906)
	Spirobolellidae	*Paraspirobolus lucifugus* (Gervais, 1836)	A	Tropical. Area of origin most likely The Seychelles and/or Mauritius	1836, FR	DE, DK, GB, NL	J100	Enghoff (1975b), Jeekel (2001), Latzel (1895), Lee (2006), Read (2008)
	Trigoniulidae	*Trigoniulus corallinus* (Gervais, 1847)	A	Southeast Asia	1902, GB	GB	J100	Pocock (1906), Shelley and Lehtinen (1999)

Table 7.2.2 List of myriapod species intercepted in Great Britain (Barber 2009a, Clarke 1938, John Lewis, *pers. comm.*, Sharon Reid (FERA), *pers. comm.*)

Species	Native Range	Found in/ Country of dispatch/ Year of Interception
Class Chilopoda		
Order Craterostigmomorpha		
Craterostigmus sp.	New Zealand & Tasmania	*Dicksonia* (Australia or New Zealand, 2008)
Order Geophilomorpha		
?*Zelanion* (= *Steneuryton*) sp.	Australia, New Zealand, Hawaii	*Dicksonia* (Australia, 2005)
Order Scolopendromorpha		
Scolopendra cingulata Latreille, 1829	Mediterranean region	With luggage (Spain, 2003), potatoes (Greece, 1975), Turkey (2004), Palestine (pre-1992)
Scolopendra dalmatica C.L. Koch, 1847	Balkan peninsula	Found in fruit & vegetable warehouse on Isle of Wight (1983)
Scolopendra subspinipes subspinipes Leach, 1815	Asia, Africa, C. & S. America	*Trachycarpus wagnerianus* (South Korea, 2006), bananas (Jamaica, 1938)
Order Lithobiomorpha		
Lithobius forficatus (Linneaus, 1758)	Europe	*Dicksonia* (Australia, 2004)
Lithobius peregrinus Latzel, 1880	Europe, Caucasus	*Dicksonia* (New Zealand, 2004)
Class Diplopoda		
Order Polydesmida		
Polydesmida gen. spp.		*Dracaena fragans* (Belgium, 1979)
?*Gasterogramma plomleyi* Mesibov, 2003	Tasmania	*Dicksonia* (Australia, 2004)
?*Mestosoma* sp.		Bromeliad (Ecuador, 1982)
Akamptogonus novarae (Humbert & Saussure, 1869)	? Australia	*Dicksonia* (New Zealand, 2004)
Habrodesmus falx Cook, 1896	West Africa	Tete leaves (Nigeria, 1981)
Habrodesmus sp.		Orchid (Malawi, 1982)
?*Oxidus gracilis*	?East Asia	Zelkova (Netherlands, 1995)
Oxidus gracilis	East Asia	Aroid (USA,1980), *Chaemaerops* (Morocco, 2001), *Cryptomeria* (Japan, 1979), *Dracaena* (Belgium, 1979), *Ficus* (West Africa, 1979), *Hibiscus* (Canary Is.), *Lirope* (USA, 1999), Orchid (Belize, 1980; Madagascar, 1995; Malaysia,1984; India, 2000), Palm (Canary Is., 1998), *Pentas* (Canary Is., 2010), *Phoenix* (USA, 1995), *Rhododendron* (soil, Nepal, 1981), *Sanseviera* (USA, 1980), *Scindapus* (soil, Nepal, 1981), *Selaginella* (Singapore, 1999; Brazil, 1995), *Serissa* (China, 1999, 2004), *Trachycarpus* (Netherlands, 2008), *Washingtonia* (Italy, 2009), Weeping fig (USA, 1984), *Yucca* (?Netherlands, 1980), *Zamia* seed (USA, 1982), *Zelkova* (China, 1995), unknown (Chile, 1998; South Africa, 2001)

Species	Native Range	Found in/ Country of dispatch/ Year of Interception
Polydesmidae		*Dicksonia* (Australia, 2005; New Zealand, 2004), Orchid (Malaysia, 1983), Wild Plant (South Africa, 1983)
Polydesmus sp.		*Miscanthus* (Dominica, 2000), Orchid (Australia, 1985)
Order Spirostreptida		
Spirostreptida		*Cyathea* (New Zealand, 2005), *Dicksonia* (Australia, 2004–2008), *Dracaena* (Rwanda, 1980)
Spirostreptus sp.		Fig (Ivory Coast, 1983)
Plusioglyphiulus sp.		Orchids & Rhododendrons (Borneo, 1979)
Order Julida		
Blaniulidae		*Echinodorus* (Singapore, 2008), Orchid (Brazil, 2003)
Blaniulus guttulatus (Fabricus, 1798)	Europe	Orchid (Australia, 1985)
Blaniulus sp.		Unknown (South Africa, 1999)
Cylindroiulus londinensis (Leach, 1814)	Europe	*Phoenix dactylifera* (Italy, 2004)
Cylindroiulus sp.		*Dicksonia* (New Zealand, 2004)
Ommatoiulus moreletii (Lucas, 1860)	Iberian peninsula	*Dicksonia* (Australia, 2006), melon fruit (South Africa, 1983)
Ommatoiulus oxypygus (Brandt, 1841)	Italy	*Vitis* sp. (Italy, 1979)
Ophyiulus targionii Silvestri, 1898	Italy	Unknown (New Zealand, 1982)

Table 7.2.3. Relative importance of the non-native species in the myriapod fauna of the Macaronesian islands. The numbers of introduced species correspond to the total non-native species of both exotic and continental European origin (cf., Arndt et al. 2008, Baéz and Oromí 2004, Borges, 2008a,b, Borges and Enghoff 2005, Enghoff 2008b, Enghoff and Borges 2005, Zapparoli and Oromi 2004), some numbers updated according to recent records. * 7 certainly native, 6 probably native, 20 possibly native, ** all probably introduced; *** all possibly native.

	Canary Isl.		Azores Isl.		Madeira Is.		Selvages Isl.	
	Native	Introduced	Native	Introduced	Native	Introduced	Native	Introduced
Diplopoda	83	24	2	19	40	18	2	0
Chilopoda	33*	2**	8	3	2	17+2?	0	2
Symphyla	0	6**	3	0	1	2	no records	no records
Pauropoda	14***	0	1	0	10	0	no records	no records

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Spiders (Araneae) Chapter 7.3

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Abstract

A total of 47 spider species are alien to Europe; this corresponds to 1.3 % of the native spider fauna. They belong to (in order of decreasing abundance) Theridiidae (10 species), Pholcidae (7 species), Sparassidae, Salticidae, Linyphiidae, Oonopidae (4–5 species each) and 11 further families. There is a remarkable increase of new records in the last years and the arrival of one new species for Europe per year has been predicted for the next decades. One third of alien spiders have an Asian origin, one fifth comes from North America and Africa each. 45 % of species may originate from temperate habitats and 55 % from tropical habitats. In the past banana or other fruit shipments were an important pathway of introduction; today potted plants and probably container shipments in general are more important. Most alien spiders established in and around human buildings, only few species established in natural sites. No environmental impact of alien species is known so far, but some alien species are theoretically dangerous to humans.

Keywords

Buildings, urban area, greenhouse, pathways, venomous spiders, Europe, alien

7.3.1 Introduction

Spiders are among the most diverse orders in arthropods with a world-wide distribution in all terrestrial habitats and more than 40,000 species, grouped in 109 families (Platnick 2008). The European spider fauna comprises nearly 3600 species of which 47 (= 1.3 %) are alien to Europe, i.e. their area of origin is outside Europe. An additional number of at least 50–100 species are alien within Europe, i.e. they originate, e.g., from the Mediterranean or from eastern parts of Europe and spread gradually into other parts of Europe. Such aliens within Europe are not considered here. Small scale spread, e.g., into an adjacent country, is also not considered here.

All spiders are predators and usually prey on arthropods, mainly insects. Since many insects are regarded as pests, spiders are often seen as beneficial. Spiders have unique features such as abdominal silk glands which are used in many ways (e.g., construction of retreat, cocoon, web or dragline) and venom glands to poison their prey (only two families deviate from this). Spiders developed many different ways to catch their prey. Roughly half of them build silken webs to subdue prey and they evolved a large variety of web types. Funnel webs are usually soil-born and closely connected to the retreat of the spider (such as Agelenidae and Amaurobiidae), sheet webs are more often found within the vegetation (examples are Linyphiidae and Theridiidae) and orb webs often bridge the open space between structures (Araneidae and Tetragnathidae). Spiders which do not build a web live as sit-and-wait predators (e.g., Clubionidae, Gnaphosidae, Lycosidae, Sparassidae, and Thomisidae) or actively hunt for prey (such as Salticidae).

For this compilation of alien spiders to Europe the DAISIE database (www.europe-aliens.org) was used. In addition a variety of further sources (cited below) was consulted. When speaking about alien species two main problems occur. (1) It may be unclear whether a species is native to Europe or not, e.g., because it is native in an area close to the European borders. This concerns primarily Mediterranean and North or East Palearctic species. We choose a very conservative attitude and did not consider such species. It may also be difficult to decide whether a Holarctic species originates in the Nearctic or in the Palearctic part of the Arctic. We tried to follow the most probable decision. (2) We included only established alien species. In some cases it may be difficult to decide on this because sometimes the discovery of an alien species is communicated but no follow-up reports on its establishment are available. Again, we tried to achieve the most probable point of view. For example, all the reports on tropical Ctenidae or Theraphosidae arriving with banana shipments in Europe never lead to an established population of these spiders and were therefore not included into our chapter.

7.3.2 Taxonomy of alien species

The 47 spider species alien to Europe belong to 17 families (Table 7.3.1) with Therididae (10 species) and Pholcidae (7 species) being the most species-rich families. Sparassidae comprise five species; Salticidae, Linyphiidae and Oonopidae comprise four species each. Eleven families are represented with only one or two species each. The most astonishing aspect of the composition of the alien spider fauna is that it neither reflects the structure of the global spider community nor the structure of the European spider fauna (Fig. 7.3.1).

Globally frequent families (such as Araneidae, Corinnidae, Lycosidae, Theraphosidae, and Zodariidae) are not represented at all among the alien species in Europe. This may be due to some specialisations or restrictions of most species in these families: Araneidae and Corinnidae are usually not associated with human infrastructure and have a rather low probability of becoming transported to foreign areas (see below). Most Theraphosidae ("tarantulas") depend on their specific microclimate and are among the largest spiders, thus easy to detect and avoid. Lycosidae were also not imported to Europe and the reason for this remains unknown.

Other families are overrepresented among the alien community: Sicariidae, Oonopidae, Sparassidae, Pholcidae, and Theridiidae. Their common feature is a preadaptation to human infrastructure, especially buildings. Many species from these families initially live on bark and rocks and/or in arid habitats, thus, they tolerate the dry climate in houses and in urban areas. They can easily sit at the vertical sides of containers (Sparassidae), hide at the underside of pallets or in cracks and cavities (Pholcidae, Theridiidae) or are simply so tiny that they fit everywhere in (Oonopidae).

The composition of the spider fauna in Europe will become strongly influenced by alien newcomers if the trend of the last decades continues. Eresidae, Prodidomidae, Scytodidae, and Oonopidae were so far rare families in Europe. Sparassidae and Pholcidae comprise only a few species and the alien add-on may lead to a situation where some families are dominated by alien species. Sicariidae did not even occur previously in Europe.

7.3.3 Temporal trends

In the past, there was hardly any systematic check for alien spiders in imported goods. In contrast to herbivores where damage to plants may be of economic importance, alien spiders were only occasionally recorded. Exceptions may be border controls of banana shipments and similar goods because such transports enabled large and dangerous animals to enter Europe. In general, information on arrival data of alien spiders is scarce and when using the date of a scientific publication as a proxy, this information may be considerably fuzzy because some publications compile data of a long period; e.g., for 26 years in Van Keer (2007).

12 first species records were collected in the 19th century, 24 records came from the 20th century and already 11 records were perceived in the first years of the 21st century. This in itself indicates a steep increase in recording alien species. Of course, it should not be overlooked that the public awareness of alien species and the number of experts increased in the last decades considerably. Both accelerate the probability of detecting new spider introductions.

Kobelt and Nentwig (2008) analysed the arrival of 87 alien spider species with known arrival date (alien to Europe and alien within Europe) and concluded that the known number of alien spider introductions still represents an underestimation. They predict a continuous trend of more alien species and give the figure of at least one additional alien spider species annually arriving in Europe in the near future.

7.3.4 Biogeographic patterns

One third of all alien spiders have an Asian origin. This may include Eastern Palearctic and Indo-Malayan, thus temperate and tropical areas. About one fifth of the species derive from North America and Africa each, and South America and Australia contribute only four species each. In a few cases the origin is not known or subjected to expert guess (Fig. 7.3.2). Such cosmopolitan species are not truly cosmopolitan because they have of course a defined area of origin, but due to early spread among many or all continents and due to lacking phylogeographical information, it is sometimes still impossible to solve such a puzzle. These results suggest that the closer a continent is (Palaearctic) and the more traffic and goods exchange exists (Asia, North America), the more alien species are also imported.

An analysis between temperate and tropical origins indicates that about 45 % of species may originate from temperate habitats and 55 % from tropical habitats. Uncertainty, however, is high because for many species nothing or not very much is known about the natural environment in which they live in their area of origin.

7.3.5 Main pathways to Europe

Kobelt and Nentwig (2008) analysed the origin of alien spider species in Europe and the intensity of trade between Europe and the native area of these alien spiders in a continent by continent comparison. By including trade volume, area size, and geographical distance, they clearly could demonstrate that trade volume, size of the area of origin, and the geographical distance to Europe are good indicators for the number of alien species transported to Europe. The volume per time curves of agricultural products and mining products fit the increase of alien spiders less well than the curve for manufactures, and therefore it is concluded that the first have a lower number of alien stowaways whereas manufactures have the highest potential to transport alien species (Fig. 7.3.3).

More in detail, spiders can survive shipment in or at containers or construction materials for periods long enough to reach most other continents. The rare collection notes on spiders which had been recorded during or after this voyage suggest that spiders frequently occur in container (e.g., with stones, wood, other products), in or at wooden boxes, at wooden pallets, and within shipments of logs or wood products. Consequently, many alien spiders are detected in a harbour, in buildings at or close to a harbour, and in or at warehouses (Van Keer 2007).

Up to the 1980s, many alien spiders were detected in banana or other fruit shipments (Forsyth 1962, Reed and Newland 2002). This does not only represent a pathway from a tropical area of origin to Europe, it also enables the spider to travel within Europe. With increasing technical standards to supply the fruits with optimal transport conditions (usually low temperature, oxygen reduction to 1–5 % and a carbon dioxide increase to 1–10 %, see also Hallman (2007)), spiders have less chances to survive this (but see Craemer 2006).

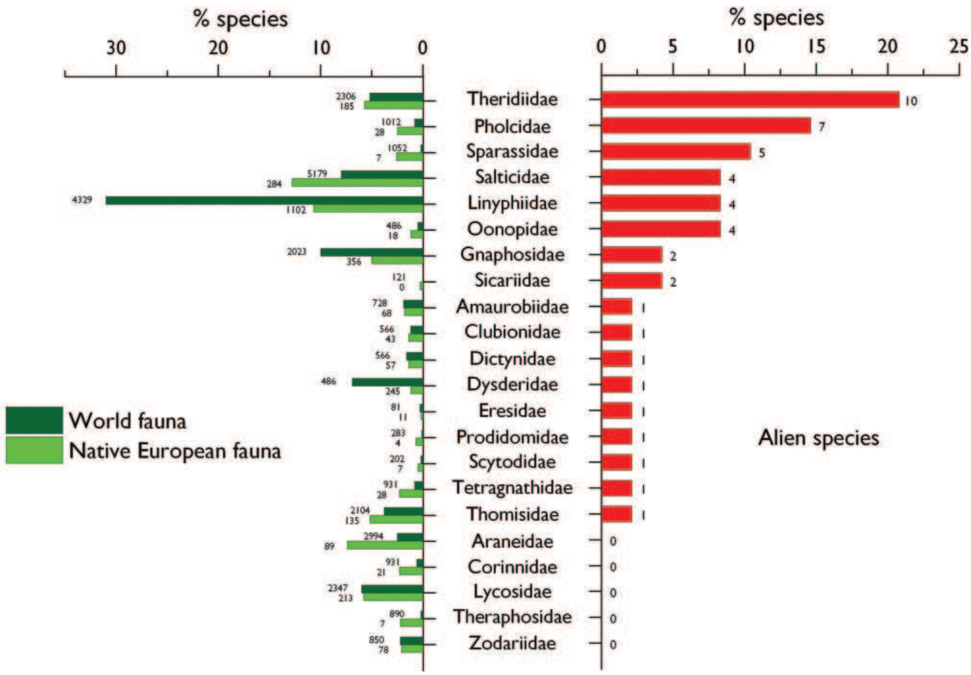

Figure 7.3.1 Taxonomic overview of the spider species alien to Europe compared to the native European fauna. Right- Relative importance of the spider families in the alien fauna expressed as the percentage of species in the family compared to the total number of alien spiders in Europe. Families are presented in a decreasing order based on the number of alien species. The number over each bar indicates the total number of alien species observed per family. Left- Relative importance of each family in the native European fauna of spiders and in the world fauna expressed as the percentage of species in the family compared to the total number of spiders in the corresponding area. The number over each bar indicates the total number of species observed per family in Europe and in the world, respectively.

Transported plants represent a very important pathway for spiders. This hardly concerns cut flowers but potted plants and plants for planting. There are numerous anecdotes that plants bought in supermarket, in a plant shop or at a plant fair contained a spider or a spider cocoon. Since a considerable amount of such potted plants is produced in China and transported through Italy to different European countries, this indicated the importance of plants as pathway from Asia to Europe.

For the further spread of alien spiders within Europe, it is assumed that transport vehicles such as trucks or trains play an important role. The spread of *Zodarion rubrum*, formerly only known from the French Pyrenees, followed in the last 100 years the main railway connections within Europe. This allowed the small spider to hitchhike over large distances (Pekár 2002). Hänggi and Bolzern (2006) discuss this phenomenon and give evidence for additional species. Spread by vehicles also may explain the fact that quite often the first record of an alien spider had been made at roadsides or in drains along roadsides (Van Keer 2007).

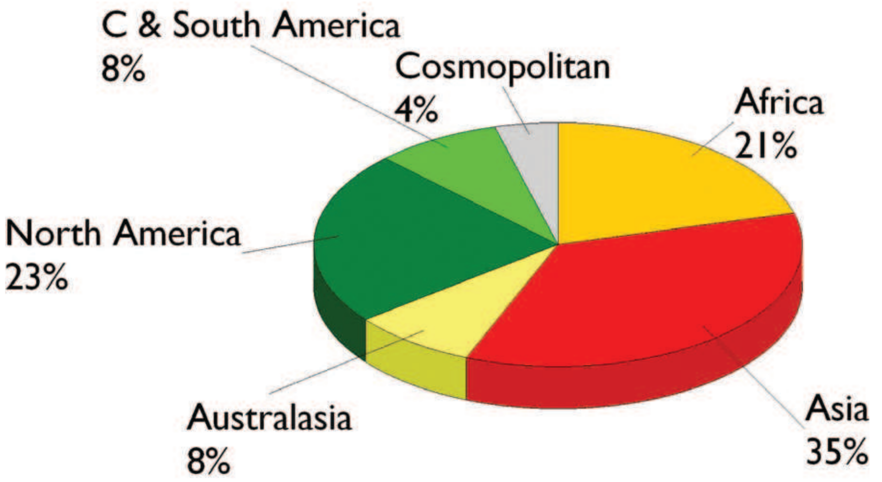

Figure 7.3.2 Geographic origin of the 47 spider species alien *to* Europe.

In a country-wise comparison within Europe, France, Belgium, The Netherlands, Germany and Switzerland possess the highest numbers of alien spider species (Fig. 7.3.4). These countries are also the ones with the highest level of imports (Fig. 7.3.5). On the other side, the Balkan countries have much lower numbers of alien spiders and Norway, the Baltic States, Belarus, and Russia have the lowest numbers of alien spiders. There is a good correlation between this type of economic activity and the number of alien species, thus, on the country level a comparable picture to the continental level of Kobelt and Nentwig (Kobelt and Nentwig 2008) is obtained.

7.3.6 Most invaded ecosystems and habitats

Nearly half of all alien spider species occur only in buildings and/or urban areas. This may be species which inhabit walls of buildings or need the specific microclimatic conditions of houses. One third of all alien species live in greenhouses, botanical gardens, in zoo buildings, or in comparably warm buildings. They rely on the specific temperature conditions but nevertheless are able to establish permanent populations (Holzapfel 1932, Van Keer 2007). In the summer season, in southern countries and under the conditions of climate change some species can colonise the vicinity of buildings and have the potential of further spread.

Only five among 47 alien spiders so far were able to establish in natural habitats. They usually are small-sized species, belonging to families which are common in Europe (Dictynidae, Linyphiidae, Tetragnathidae), and they build sheet webs or small orb webs. They originate from North America, Japan and the temperate part of Australia or New Zealand. These parameters probably indicate the conditions which an alien spider should fulfil to be able to survive in natural habitats in Europe.

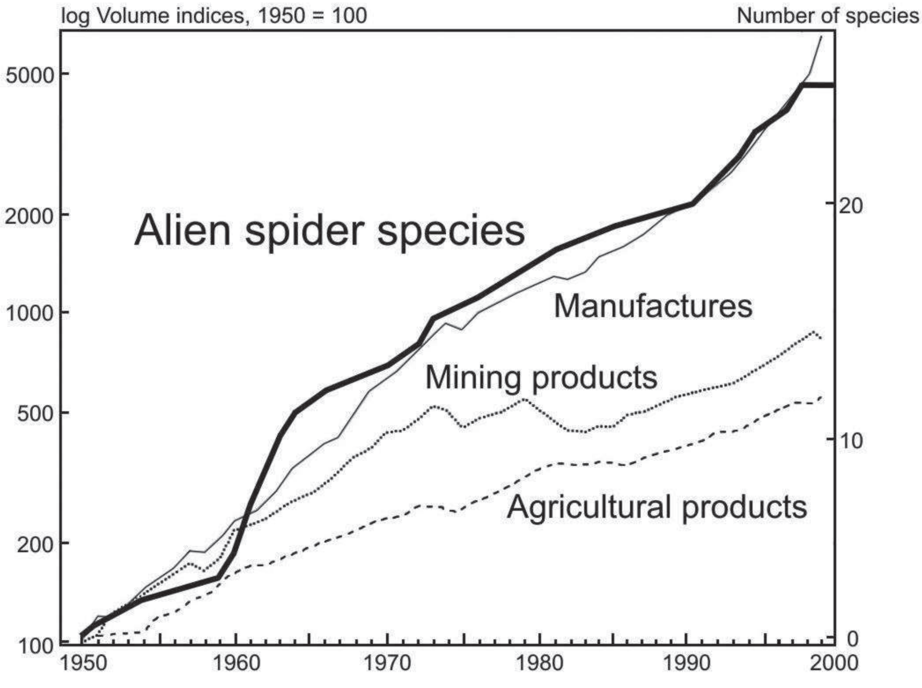

Figure 7.3.3 Increase in global trade (left scale) and the cumulative number of alien spider species introductions (right scale) during the last 50 years. Only cases with known year of introduction are included - from Kobelt and Nentwig (2008).

An interesting reason for the obvious high establishment success of alien spiders in human buildings may be found in the rarity of native species at such conditions. This could mean that alien species have much better chances to establish in habitats with no competition by native species.

7.3.7 Ecological and economic impact

A family-wise comparison of body sizes of alien and European spider species showed that alien Theridiidae imported to Europe were significantly larger than the native species, Pholcidae and Salticidae showed a trend into the same direction. Kobelt and Nentwig (2008) argue that this reflects the physical transport conditions, especially of temperature and humidity inside a standard ship container (Diepenbrock and Schieder 2006, Naber et al. 2006). These are important stress factors which primarily affect small specimen and can be more easily compensated by large spiders (Pulz 1987). So, even if spiders of all body sizes and from all continents would have more or less equal possibilities to be shipped around the globe, larger species have better chances to survive transportation than smaller ones do.

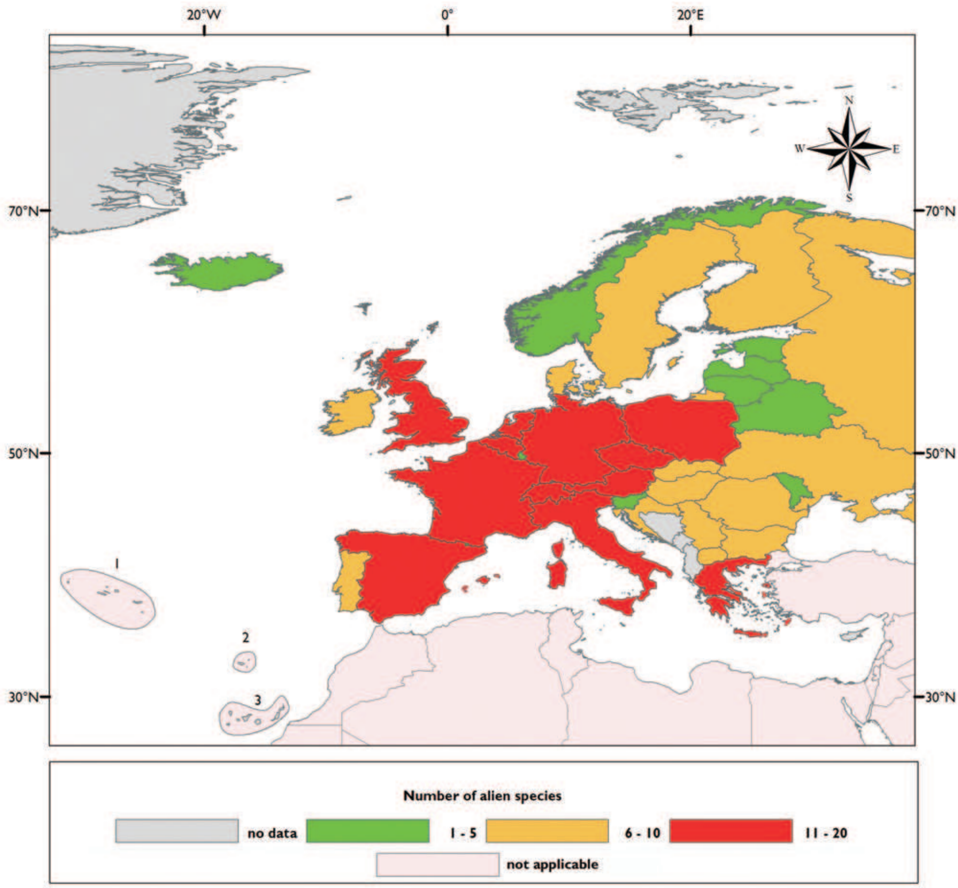

Figure 7.3.4 Number of alien spider species for each European country.

If alien species could successfully invade European spider assemblages in natural habitats, it could be argued that due to their slightly larger body size they could compete with native species and suppress or even replace them. This would change the dominance structure in natural spider communities within a few years. So far, however, most alien species do not occur in natural spider communities and / or remained rare. Therefore, in Europe no influence of alien spider species on native spiders had been observed so far. This is in agreement with a two-year-analysis of spider communities in California were the occurrence of alien spider species did not negatively affect native species. The most productive habitats contained both the highest proportion of alien and the greatest number of native spiders. No negative associations between native and alien spiders could be detected and, thus, Burger et al. (2001) concluded that the alien spiders do not impact native ground-dwelling spiders.

The most frequently occurring alien spider in Europe is probably the North American linyphiid *Mermessus trilobatus,* first detected in southern Germany in the 1980s and spreading since then. Only in the last years it had been detected that it obviously easily

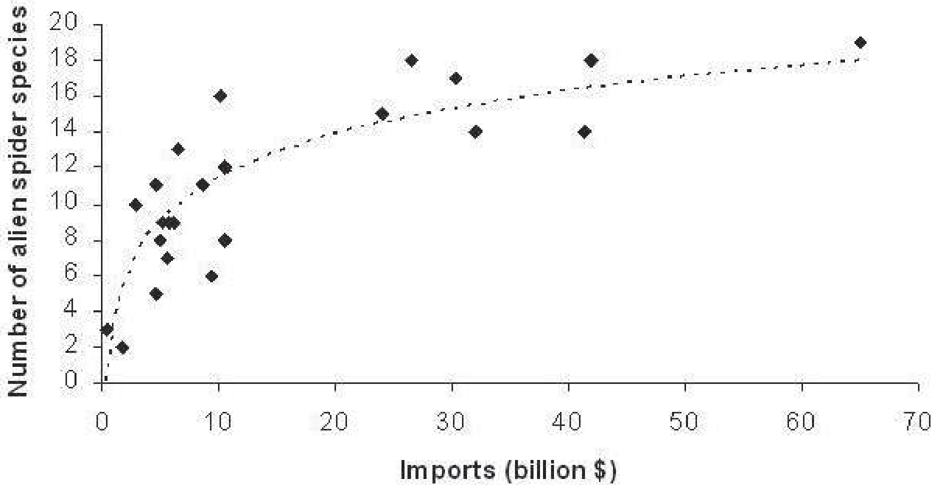

Figure 7.3.5 Relationship between the number of alien spider species and the value of imported goods in European countries (economic data for 2005).

establishes in many natural spider communities, especially in grassland and ruderal habitats (Schmidt et al. 2008). With an average body length of 1.6–2.1 mm (Nentwig et al. 2003), *M. trilobatus* belongs to the smaller linyphiids and it is unlikely that it outcompetes a native species. Competition experiments indeed proved that the invasion success of *M. trilobatus* is not facilitated by strong competitiveness. Actually it is unknown if other traits (e.g., higher reproduction effort, better dispersal abilities, or nutritional aspects) give some competitive advantage over native species (Eichenberger et al. 2009). So far, the integration success of *M. trilobatus* into native spider communities seems to confirm the assumption of Burger et al. 2001 on the resilience of native spider communities.

An economic impact of spiders may be expected from those spider species which are venomous to humans. Among the alien spiders listed here (Table 7.3.1) species which may be considered as theoretically dangerous to humans comprise the sicariids *Loxosceles laeta* and *L. rufescens* and the Australian black widow *Latrodectus hasselti* (Forster 1984). We are, however, not aware of any report from Europe referring to bites from these species. This is in line with the general assumption that the frequency of spider bites is overestimated (Vetter et al. 2003). Additionally it may be possible that these alien species did not reach relevant densities or that they even did not establish in the long term.

Spiders are also known to pollute the faces of buildings and the interior of rooms by their silk spinning activity. Spider webs often stay for long, collect dust and dirt, and are the reason for additional cleaning procedures which cause costs for hygienic reasons. There are only very few reports on this and they only refer to the Mediterranean dictynid spider *Dictyna civica* spreading since more than 50 years in Central Europe (Billaudelle 1957, Hertel 1968) which occasionally colonises the outside surface of buildings in high densities. Also many native species live inside buildings and cause

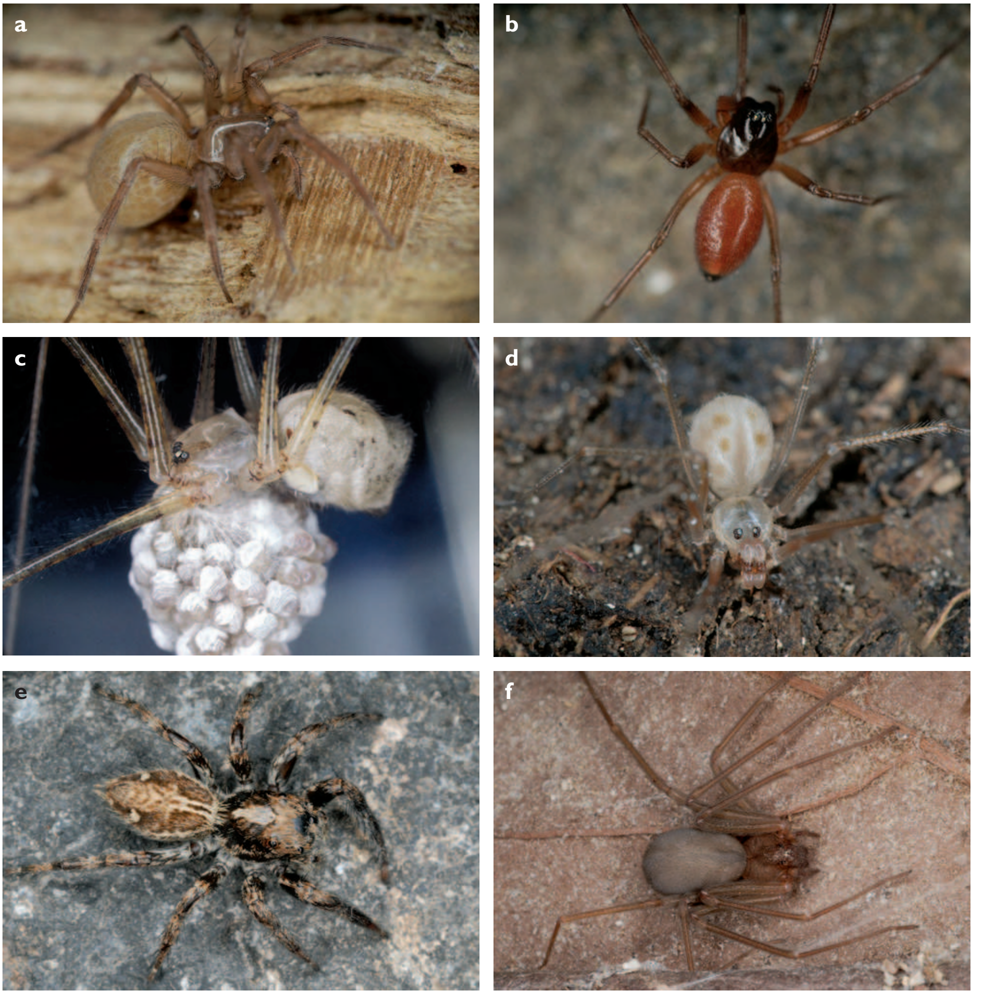

Figure 7.3.6. Alien spiders. **a** *Cicurina japonica* female (Dictynidae) **b** *Ostearius melanopygius* female (Linyphiidae) **c** *Crossopriza lyoni* female with eggsac (Pholcidae) **d** *Spermophora senoculata* male (Pholcidae) **e** *Plexipus paykulli* female (Salticidae) **f** *Loxosceles rufescens* female (Sicariidae). Reprinted with kind permission of Jørgen Lissner (© Jørgen Lissner, http://www.jorgenlissner.dk).

regular cleaning activities due to their web spinning activity but no report concerns additional cleaning costs. Since alien species are much less abundant, such additional costs are not to be expected or they will be merged with cleaning costs which anyhow have to be achieved. In addition, it should not be underestimated that many people simply fear spiders and react with insecticidal applications which involves financial costs and may cause health problems. This, however, concerns native and alien spiders likewise.

Acknowledgements

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References

Billaudelle H (1957) Zur Biologie der Mauerspinne *Dictyna civica* (H. LUC.) (Dictynidae: Araneida). *Zeitschrift für angewandte Entomologie* 41: 475–512.

Blick T (ed) (2004) *Checklist of the spiders of Central Europe (Arachnida: Araneae)*. http://www.arages.de/checklist.html#2004_Araneae

Blick T, Hänggi A (2003) *Invasive Spinnentiere (Arachnida ohne Acari) in der Schweiz*. Delémont, Switzerland: CABI Bioscience Switzerland Centre.

Bosmans R, Vanuytven H (2002) Een herziene soortenlijst van de Belgische spinnen (Araneae). *Nieuwsbrief Belgische Arachnologische Vereniging* 16: 44–80.

Burger JC, Patten MA, Prentice TR, Redak RA (2001) Evidence for spider community resilience to invasion by non-native spiders. *Biological Conservation* 98: 241–249.

Craemer C (2006) Spiders a problem on export grapes. *Plant Protection News* 67: 10

Deeleman-Reinhold CL, Deeleman P (1988) Révision des Dysderinae (Araneae, Dysderidae), les espèces méditerranéennes occidentales exceptées. *Tijschrift Voor Entomologie* 131: 141–269.

Diepenbrock B, Schieder U (2006) Transport information service, Version 1.8.0.06. Gesamtverband der Deutschen Versicherungswirtschaft, Berlin. http://www.tis-gdv.de

Eichenberger B, Siegenthaler E, Schmidt-Entling MH (2009) Body size determines the outcome of competition for webs among exotic and native sheetweb spiders (Araneae: Linyphiidae). *Ecological Entomology* 34: 363–368.

Entling W, Schmidt MH, Bacher S, Brandl R, Nentwig W (2007) Niche properties of Central European spiders: shading, moisture and the evolution of the habitat niche. *Global Ecology and Biogeography* 16: 440–448.

Fauna Europaea (2005) *Fauna europaea, Version 1.2 from 7 March 2005*. http://www.faunaeur.org

Forster LM (1984) The Australian redback spider (*Latrodectus hasselti*): its introduction and potential for establishment and distribution in New Zealand. In: Laird M (Ed) *Commerce and the spread of pests and disease vectors*. New York: Praeger, 273–289.

Forsyth M (1962) Spiders introduced with fruit to Northern Ireland during 1961. *Irish Naturalists' Journal* 14: 63.

Hallman GJ (2007) Phytosanithary measures to prevent the introduction of invasive species. in Nentwig W (Ed) *Biological invasions*. Berlin: Springer, 367–384.

Hänggi A (2003) Nachträge zum 'Katalog der schweizerischen Spinnen' 3. Neunachweise von 1999 bis 2002 und Nachweise synanthroper Spinnen. *Arachnologische Mitteilungen* 26: 36–54.

Hänggi A, Bolzern A (2006) *Zoropsis spinimana* (Araneae: Zoropsidae) neu für Deutschland. *Arachnologische Mitteilungen* 32: 8–10.

Harvey R, Nellist DR, Telfer MG (eds) (2002) *Provisional atlas of British spiders (Arachnida, Araneae)*. Huntingdon, UK: Biological Records Centre. 214 pp.

Hertel R (1968) Über das Auftreten der südeuropäischen Spinne *Dictyna civica* (H.LUC.) in Dresden (Dictynidae, Araneida). *Abhandlungen des Naturkundemuseums Görlitz* 44: 89–94.

Holzapfel M (1932) Die Gewächshausfauna des Berner Botanischen Gartens. *Revue Suisse de Zoologie* 39: 325–374.

Huhta V (1972) *Loxosceles laeta* (Nicolet) (Araneae, Loxoscelinae), a venomous spider established in a building in Helsinki, Finland, and notes on some other synanthropic spiders. *Annales Entomologici Fennici* 38: 3.

Jäger P (2005) *Zimiris doriai* (Araneae: Prodidomidae) – erstmals nach Deutschland eingeschleppt. *Arachnologische Mitteilungen* 29: 17–19

Kobelt M, Nentwig W (2008) Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Komposch C (2002) Spinnentiere: Spinnen, Weberknechte, Pseudoskorpione, Skorpione (Arachnida: Araneae, Opiliones, Pseudoscorpiones, Scorpiones). In: Essl F, Rabitsch W (Eds) *Neobiota in Österreich*. Wien: Umweltbundesamt. 432 pp.

Koponen S (1997) *Triaeris stenaspis* Simon (Araneae, Oonopidae) found in the botanical garden of the University of Turku, Finland. *Entomologica Fennica* 8: 7.

Lee P (2005) An imported pholcid in Felixstowe. *Newsletter of the British Arachnological Society* 102: 7.

Montardi Y (2006) *Catalogue of French Salticidae*. http://saitis.club.fr/montardi/salticidae/catalogue/catalogue_frame.html

Naber G, Duken U, Mast EW, Schieder UP (2006) *Container handbook*. Gesamtverband der Deutschen Versicherungswirtschaft, Berlin. http://www.containerhandbuch.de [accessed 28 June 2006]

Nentwig W, Hänggi A, Kropf C, Blick T (2003) *Central European spiders determination key*. www.araneae.unibe.ch [accessed 8.12.2003]

Pekár S (2002) Revision of the genus *Zodarion* (Araneae: Zodariidae) in the Czech and Slovak Republics. *Acta Societatis Zoologicae Bohemiensis* 66: 51–66.

Platnick NI (2008) The world spider catalog, Version 9.0. http://research.amnh.org/entomology/spiders/catalog/INTRO1.html

Pulz R (1987) Thermal and water relations. In: Nentwig W (Ed) *Ecophysiology of spiders*. Berlin: Springer, 26–55.

Reed C, Newland S (2002) Spiders associated with table grapes from United States of America (State of California), Australia, Mexico and Chile. Wellington, New Zealand: MAF Biosecurity Authority, Ministry of Agriculture and Forestry. 90 pp.

Ruzicka V (1995) The spreading of *Ostearius melanopygius* (Araneae: Linyphiidae) through Central Europe. *European Journal of Entomology* 92: 723–726.

Saaristo MI (2003) Tetragnathid spiders of Seychelles (Araneae, Tetragnathidae). *Phelsuma* 11: 13–28.

Sacher P (1983) Spinnen (Araneae) an und in Gebäuden. Versuch einer Analyse der synanthropen Spinnenfauna in der DDR, 1.Teil. *Entomologische Nachrichten und Berichte* 27: 97–104.

Schmidt MH, Rocjer S, Hanafi J, Gigon A (2008) Rotational fallows as overwintering habitat for grass-land arthropods: the case of spiders in fen meadows. *Biodiversity and Conservation* DOI 10.1007/s10531–008–9412–6

Slawson C (2000) Staffordshire biodiversity action plan, Araneae (Arachnida) – spiders. 2nd edn. http://www.sbap.org.uk/focal/checklst/araneae.htm

Terhivuo J (1993) Novelties to the Finnish spider fauna (Araneae) and notes on species having bitten man. *Memoranda Societatis Fauna Flora Fennica* 69: 53–56.

Valesova-Zdarkova E (1966) Synanthrope Spinnen in der Tschechoslowakei. *Senckenbergiana Biologica* 47: 73–75.

Van Keer K (2007) Exotic spiders (Araneae): Verified reports from Belgium of exported species (1976–2006) and some notes on apparent neozoan invasive species. *Nieuwsbrief Belgische Arachnologische Vereniging* 22: 45–54.

Vetter RS, Cushing PE, Crawford RL, Royce LA (2003) Diagnoses of brown recluse spider bites (loxoscelism) greatly outnumber actual verifications of the spider in four western American states. *Toxicon* 42: 413–418.

Wunderlich J, Hänggi A (2005) *Cicurina japonica* (Araneae: Dictynidae) eine nach Mitteleuropa eingeschleppte Kräuselspinnenart. *Arachnologische Mitteilungen* 29: 20–24.

Table 7.3.1 List and main characteristics of the spider species alien to Europe. Area of origin: since the area of origin is quite often not well known, this refers to the most probable origin. "cosmopolitan" means that the area of origin is outside Europe but not known, "cosmopolitan" in brackets gives an alternative explanation, South America refers to the tropical part of America. Country codes abbreviations refer to ISO 3166 (see appendix I). Only selected references are given. Last update 30.09.2008.

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Amaurobiidae					
Amaurobius similis (Blackwall 1861)	North America (cosmopolitan)	1915, DK	AD, BE, CH, DK, DE, ES, FR, GB, IE, MD, NL, NO, PL, RO, SE, UA	J1	Fauna Europaea (2005), Harvey (2002), Sacher (1983), Jonsson pers. comm. (2005), Scharff pers. comm. (2005)
Clubionidae					
Clubiona facilis O. P.-Cambridge 1910	Australia	1932, GB	GB	U	Fauna Europaea (2005), Platnick (2008)
Dictynidae					
Cicurina japonica (Simon 1886)	Asia	1990, DE	DE, CH, DK	E, F, G, H, I	Blick and Hänggi (2003), Wunderlich and Hänggi (2005)
Dysderidae					
Dysdera aculeata Kroneberg 1875	Asia	1988 HR	HR	U	Deeleman-Reinhold and Deeleman (1988)
Eresidae					
Seothyra perelegans Simon 1906	Africa	1906 FR	FR	U	Fauna Europaea (2005)
Gnaphosidae					
Sosticus loricatus (L. Koch 1866)	Asia	1879, SK	AT, BG, BY, CS, CZ, DE, EE, FI, FR, GR, HU, IT, LV, LT, MK, PL, RO, RU, SK	J1	Fauna Europaea (2005), Sacher (1983), Terhivuo (1993), Pekar pers. comm. (2005)
Zelotes puritanus Chamberlin 1922	North America	1966, CZ	AT, CH, CR, CZ , DE, LI, NO, RU, SE, SK	J1	Fauna Europaea (2005), Komposch (2002), Pekar pers. comm. (2005)
Linyphiidae					
Erigone autumnalis Emerton 1882	North America	1990, CH	CH, IT	E, F, G, H, I	Blick and Hänggi (2003), Fauna Europaea (2005)
Mermessus denticulatus (Banks, 1898) (=*Eperigone eschatologica*)	North America	1995, BE	BE, CH, DE, ES, NL	J1, J2.43	Blick (2004), Blick and Hänggi (2003), Fauna Europaea (2005)
Mermessus trilobatus (Emerton 1882)	North America	1980, DE	AT, BE, CH, DE, IT, PL	E, F, G, H, I	Blick and Hänggi (2003), Fauna Europaea (2005)
Ostearius melanopygius (O. P.-Cambridge 1879)	Australia	1906, GB	AT, BE, BG, CH, CZ, DE, DK, ES, FR, FI, GB, IT, NL, PT, PL, RO, SE, SK	E, F, G, H, I	Blick and Hänggi (2003), Fauna Europaea (2005), Komposch (2002), Ruzicka (1995), Pekar pers. comm. (2005), Scharff pers. comm. (2005)

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habi-tats**	**Refs**
Oonopidae					
Diblemma donisthorpei O. P.-Cambridge 1908	Asia	1914, GB	GB	J1	Platnick (2008), Saaristo (2003)
Ischnothyreus lymphaseus Simon 1893	Asia	2005, FR	FR	U	Fauna Europaea (2005)
Ischnothyreus velox Jackson 1908	Asia	2003, DE	DE, GB, NL	J2.43	Blick (2004), Fauna Europaea (2005), Saaristo (2003)
Triaeris stenaspis Simon 1891	North America	1896, FR	BE, FI, FR, IE, SK	J1, J100	Blick (2004), Fauna Europaea (2005), Holzapfel (1932), Koponen (1997), Van Keer (2007), Pekar pers. comm. (2005)
Pholcidae					
Artema atlanta Walckenaer 1837	Africa	2001 BE	BE, GB, GR	J1	Blick (2004), Blick and Hänggi (2003), Fauna Europaea (2005), Lee (2005), Platnick (2008), Van Keer (2007)
Crossopriza lyoni (Blackwall 1867)	Africa	2004, BE	BE	E, F, G, H, I, J1	Blick (2004), Van Keer (2007)
Micropholcus fauroti (Simon 1887)	Africa	2001, BE	BE, CH	J1	Blick (2004), Blick and Hänggi (2003), Platnick (2008), Van Keer (2007)
Pholcus opilionoides (Schrank 1781)	Asia	1859, CZ	AD, AT, BG, CH, CS, CZ , DE, ES, FR, GR, HR, HU, IT, LI, LU, MD, MK, MT, PL, PT, RO, RU, SK, UA	J1	Fauna Europaea (2005), Sacher (1983), Pekar pers. comm. (2005)
Pholcus phalangioides (Fuesslin 1775)	Asia	1857, SK	AT, BE, BG, BY, CH, CS, CZ , DE, DK, ES, FI , FR, GB, GR, HU, IE, IS, IT, LI, LT, LU, MD, MK, MT, NO, NL, PL, PT, RO, RU, SE, SK, UA	J1	Fauna Europaea (2005), Holzapfel (1932), Komposch (2002), Sacher (1983), Terhivuo (1993), Valesova-Zdarkova (1966), Jonsson pers. comm. (2005), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Smeringopus pallidus (Blackwall 1858)	Africa	2004, NL	NL	J1, J2.43	Blick (2004)
Spermophora senoculata (Dugès 1836)	Africa	1976, SK	BE, BG, CH, CS, ES, FR, GR, HR, IT, MK, MT, PT, SI, SK, UA	J1, J100	Blick (2004), Fauna Europaea (2005), Platnick (2008), Pekar pers. comm. (2005)

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Prodidomidae					
Zimiris doriai Simon 1882	Asia	2005, DE	DE	J1	Jäger (2005)
Salticidae					
Hasarius adansoni (Audouin 1826)	Africa	1901, FR	BE, CH, CZ, DE, DK, ES, FR, GR, IE, IT, MT, NL, PL	J2.43	Blick and Hänggi (2003), Bosmans and Vanuytven (2002), Fauna Europaea (2005), Hänggi (2003), Holzapfel (1932), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Menemerus bivittatus (Dufour 1831)	Africa	1831, ES	CZ, ES, FR, GB, IT, PT	J1	Fauna Europaea (2005), Montardi (2006)
Panysinus nicholsoni (O. P.-Cambridge 1899)	Asia	2005, FR	FR	J1	Fauna Europaea (2005)
Plexippus paykulli (Audouin 1826)	Asia	1819, FR	ES, FR, GB, GR, IT, MT	J1	Fauna Europaea (2005), Montardi (2006)
Scytodidae					
Scytodes venusta (Thorell 1890)	Asia	2004, NL	NL	J1	Blick (2004), Fauna Europaea (2005), Platnick (2008), Pekar pers. comm. (2005)
Sicariidae					
Loxosceles laeta (Nicolet 1849)	South America	1963, FI	FI, IT	J1	Fauna Europaea (2005), Huhta (1972)
Loxosceles rufescens (Dufour 1820)	North America (cosmopolitan)	1820, ES	ES, FR, GR, HR, IT, NL, MT, PT	J1, J2.43	Blick (2004), Fauna Europaea (2005)
Sparassidae					
Barylestis scutatus (Pocock 1903)	Africa	1961, IE	IE	J1	Forsyth (1962)
Barylestis variatus (Pocock 1899)	Africa	1961, IE	GB, IE	J1	Forsyth (1962), Slawson (2000)
Heteropoda venatoria (Linnaeus 1767)	Asia	1960, CZ	CH, CZ, DE, DK, ES, NL, NO, PL	J2.43	Blick and Hänggi (2003), Fauna Europaea (2005), Hänggi (2003), Ruzicka (1995), Valesova-Zdarkova (1966), Ruzicka pers. comm. (2005), Scharff pers. comm. (2005)
Olios sanctivincentii (Simon 1897)	Asia	1961, IE	GB, IE	J1	Forsyth (1962), Slawson (2000)
Tychicus longipes (Walckenaer 1837)	Asia	1837, NL	NL	J2.43	Platnick (2008)

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Tetragnathidae					
Tetragatha shoshone (Levi 1981)	North America	1992, DE	AT, CZ, DE, HU, MK, RO, SK	E, F, G, H, I	Fauna Europaea (2005)
Theridiidae					
Achaearanea tabulata Levi 1980	South America	1991, AT	AT, CH, DE, PL, RU, BG, UA	J1	Blick and Hänggi (2003), Fauna Europaea (2005)
Achaearanea acoreensis (Berland 1932)	North America	2002, BE	BE	J1, J2.43	Van Keer (2007)
Achaearanea tepidariorum (C.L. Koch 1841)	South America (cosmopolitan)	1867, AT	AT, BE, BG, CH, CZ, DE, DK, ES, FI, FR, GB, GR, HU, HR, IE, IS, IT, LV, LI, MK, MT, NL, NO, PL, PT, RO, RU, SK, SE, UA	J1	Fauna Europaea (2005), Komposch (2002), Sacher (1983), Valesova-Zdarkova (1966), Koponen pers. comm. (2005), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Achaearanea verruculata (Urquhart 1885)	Australia	1885, BE	BE, GB	J1, J2.43	Blick (2004), Platnick (2008), Van Keer (2007)
Chrysso spiniventris (O. P.-Cambridge 1869)	Asia	1949, NL	NL	J2.43	Blick (2004)
Coleosoma floridanum Banks 1900	Asia	1981, GB	AT, CH, DE, FI, GB, NL	J1, J2.43	Blick (2004), Blick and Hänggi (2003), Fauna Europaea (2005), Hänggi (2003), Harvey (2002), Komposch (2002)
Latrodectus hasselti Thorell 1870	Australia	2001, BE	BE, DK	J2.43	Blick (2004), Platnick (2008), Scharff pers. comm. (2005)
Nesticodes rufipes (Lucas 1846)	South America	1996, AT	AT, BE, CZ, ES, MT, PT	J2.43	Blick (2004), Komposch (2002), Van Keer (2007)
Steatoda grossa (C.L. Koch 1838)	Cosmopolitan	1850, SE	AT, BE, BG, BY, CS, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LT, LV, MD, MK, MT, NL, PL, PT, RO, RU, SE, SI, SK , UA	J1	Fauna Europaea (2005), Komposch (2002), Sacher (1983), Valesova-Zdarkova (1966), Jonsson pers. comm. (2005), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Steatoda triangulosa (Walckenaer 1802)	Cosmopolitan	1852, AT	AD, AT, BE, BG, CH, CS, CZ, DE, ES, FR, GB, GR, HR, HU, LV, MK, MT, NL, PT, RO, RU, SI, SK, UA	J1	Fauna Europaea (2005), Harvey (2002), Komposch (2002), Valesova-Zdarkova (1966), Scharff pers. comm. (2005)
Thomisidae					
Bassaniana versicolor Keyserling 1880	North America	1932, FR	FR	U	Fauna Europaea (2005)

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Mites and ticks (Acari)
Chapter 7.4

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Abstract
The inventory of the alien Acari of Europe includes 96 species alien to Europe and 5 cryptogenic species. Among the alien species, 87 are mites and 9 tick species. Besides ticks which are obligate ectoparasites, 14 mite species belong to the parasitic/predator regime. Among these species, some invaded Europe with rodents (8 spp.) and others are parasitic to birds (2 spp). The remaining 77 mite species are all phytophagous and among these 40% belong to the Eriophyidae (37 spp.) and 29% to the Tetranychidae (27 spp.) families. These two families include the most significant agricultural pest. The rate of introductions has exponentially increased within the 20th century, the amplification of plant trade and agricultural commodities movements being the major invasion pathways. Most of the alien mite species (52%) are from North America, Asia (25%), and Central and South America (10%). Half of the ticks (4 spp.) alien *to* Europe originated from Africa. Most of the mite species are inconspicuous and data regarding invasive species and distribution range is only partially available. More research is needed for a better understanding of the ecological and economic effects of introduced Acari.

Keywords
Europe, alien, mite, tick, Acari, Eriophyidae, Tetranychidae, biological control, *Tetranychus evansi*, *Oligonychus perseae*, *Polyphagotarsonemus latus*, *Brevipalpus californicus*, *Aceria sheldoni*, *Aculops pelekassi*, *Dermatophagoides evansi*, *Varroa destructor*

7.4.1. Introduction

The subclass Acari, which includes mites and ticks, forms an important part of the class Arachnida, with a worldwide distribution and with over 55,000 (Krantz and Walter 2009) species described to date. An estimate of up to half a million to a million more species await discovery (Krantz and Walter 2009). Mites and ticks are a very diverse group ranging in size from about 0.08 mm up to 1 centimetre long. Acari differ from others Arachnida by the fusion of the abdominal segments as in Araneae (spiders) and from spiders by the presence of a gnathosoma containing mouthparts, the fusion of the posterior part of the prosoma (the podosoma, bearing legs) and fusion of an opisthosoma into an idiosoma (Evans et al. 1996). Most species are free living and have different trophic modes, including phytophagous, predators feeding on a variety of small invertebrates, fungivores and detritivores. Some species have developed complex parasitic relationships with both vertebrate and invertebrate animals. A number of acarine groups are injurious to crops and to livestock, both because of their feeding activities and because of their capacity as vectors for a variety of disease organisms to their plant or animal host. While the Oribatida is an important group (more than 6,000 species) having a key role in soil equilibrium, data regarding invasive species and distribution range remain largely unavailable. Ticks are very peculiar acarines, since they are obligate ectoparasites. In this sense they form a very homogenous group, with the order Ixodida composed of only three families. In this chapter, the two groups of Acari, mites and ticks, will be treated separately. The ticks will be presented through the description of a few significant case studies. By contrast, mites being much diversified in their biology and habitat use, and being truly ubiquitous, will be presented systematically.

Mites have successfully colonized nearly every known terrestrial, marine, and freshwater habitat. The most studied and observed invaders are found among the phytophagous mites of the families Tetranychidae and Eriophyidae, which include important agricultural pests. There is a growing awareness of the economic relevance of eriophyids as crop pests, including their importance as vectors of plant viruses, their role as alternative food for predators of plant pests, and their potential as weed control agents (Sabelis and Bruin 1996). A description on spider mite biology and their control is presented in the extensive review by Helle and Sabelis (1985). In addition to plant-feeding mites, a second group includes the alien parasitic mites. Among them, some invaded Europe with rodents such as muskrats (six alien species of mites), and brown rats (two aliens), while others are bird parasites (two species). *Dermatophagoides evansi* (Pyroglyphidae) is not associated with rodents and it has probably been accidentally introduced by humans (Bigliocchi and Maroli 1995,Hughes 1976,Thind and Clarke 2001). A single species in the family Varroidae, *Varroa destructor,* is alien to Europe (De Rycke et al. 2002, Griffiths and Bowman 1981).

Ticks are important parasites of livestock, wild animals, and humans. After their parasitic phase, they spend most of their life cycle outside their hosts, where prevailing climate conditions may constrain their ability to colonize a given territory. While some tick species are highly restricted to particular combinations of climatic variables, or have defined host species, others may occur in widely variable climate conditions and have catholic feeding habits. Some species of ticks can be considered as invasive species, since the uncontrolled movements of domestic animals may introduce alien species into Europe or disperse some species outside their native distribution ranges. The introduction via large-bodied host vectors (such as passerine birds) and the uncontrolled importation of reptiles, are important means for colonizing newly available areas. Furthermore, one species of tick, *Rhipicephalus sanguineus,* is spreading in parts of Europe out of its current range because of the movements of domestic dogs.

7.4.2 Taxonomy of the mite species alien *to* Europe

A total of 101 mite species have been considered as alien to Europe, including 96 species shown to have originated from other continents and 5 cryptogenic species (Table 7.4.1). These species involve 16 different families of mites (Figure 7.4.1). In addition, Table 7.4.2 provides some examples of mite species alien *in* Europe; i.e., European species introduced from one part of Europe to another where they are not native.

Alien mites belong to two super orders, **Acariformes (Actinotrichida)** and **Parasitiformes (Anactinotrichida)**. Most of these species belong to two orders of Acariformes, **Prostigmata** and **Astigmata**. Prostigmata includes the three most important superfamilies:

* **Tetranychoidea** comprises two main families containing alien mites. The Tetranychidae family, or spider mites, includes 1,250 described species (http://www1.montpellier.inra.fr/CBGP/spmweb/). Among them, 100 can be considered as pests and 10 as major pests of agricultural crops. All stages are phytophagous and feed on parenchyma cells. No viruses associated with spider mites have been observed. The most widely distributed species is the highly polyphagous and ubiquitous *Tetranychus urticae* (two spotted spider mite), found on nearly 1,000 plant species. In Europe, alien spider mites are generally more specialized and occur on a single genus or family of plants. Due to their minute size (200 to 900 µm) typical of many species of Acari, spider mites remain undetected until major plant damage occurs. The members of another family, Tenuipalpidae*,* or false spider mites, are important obligate phytophagous mites. They are elongate, dorsoventrally flattened and usually have a reddish colour.

* **Eriophyoidea** includes three families:

– Eriophyidae, to which belong ca. 88% of all known Eriophyoidea in the fauna of Europe (Fauna Europaea 2009). These are vermiform, four legged mites. The family includes important economic pests of broadleaved plants. All known mite vectors of plant pathogens and nearly all gall-forming species belong to this family. About half are vagrants. Most of the species in the genera *Aceria* and *Eriophyes* cause specific galls on the leaves, green twig, flower buds, vegetative buds, or fruit of the hosts (Oldfield 1996). Others, especially *Epitrimerus, Phyllocoptes, Aculops* and *Aculus* cause discolouration and other non-distortive damage to their hosts.

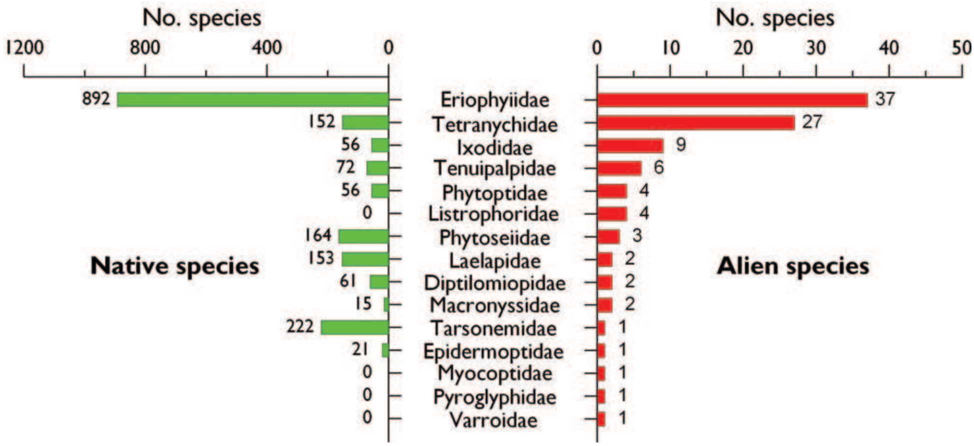

Figure 7.4.1. Relative importance of the mite families in the alien and native fauna in Europe. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. Only the most important families of native species (> 50 spp.) have been considered. The number over each bar indicates the number of species observed per family.

– Phytoptidae, which are obligate phytophagous and gall mites, with a high degree of specificity. They are also vermiform and four-legged. The family Phytoptidae is well represented on conifers (half of the described phytoptid species) and monocots. Phytoptidae is less represented than Eriophyidae or Diptilomiopidae on dicotyledons. Four alien species out of a total of 56 species have been reported in the fauna of Europe.

– Diptilomiopidae, which are predominantly leaf vagrants, only inhabiting leaves of dicotyledons, and rarely causing notable damage to their hosts (Keifer 1975). Two monotypic genera are known from only two families of monocotyledons (Poaceae and Palmae) occurring in the tropics. *Rhyncaphytoptus* species are mainly represented on several families of deciduous trees in the Holarctic region. Two alien species have been reported, out of the total 61 in the European fauna.

* **Tarsonemoidea** represented by the family Tarsonemidae includes economically important mites. Most of them are mycophagous. Some species are phytophagous, whereas others are parasites of bark beetle eggs, or predators of tetranychid eggs. The most redoubtable pest species in the family is the broad mite, *Polyphagotarsonemus latus* (=*Hemitarsonemus latus*), which was described in 1890 and has recently been redefined and considered as being a species complex (Gerson 1992).

The order **Astigmata** is less represented in the alien fauna. A few species belong to the super-family **Sarcoptoidea**, and especially to families Listrophoridae and Myocopidae. Members of Listrophoridae are usually small, elongate mites and are skin or hair parasites of mammals. The palpae and/or legs I-II are often highly modified for grasping hairs. Four species of Listrophoridae mites have invaded Europe, grasped to the fur of muskrats: *Listrophorus americanus*, *L. dozieri*, *L. faini* and *L. validus* (Šefrová and Laštůvka 2005). Myocopids, or hair mites, live on skin of marsupial and rodents (Bauer and Whitaker 1981, Šefrová and Laštůvka 2005, Whitaker 2007). *Myocoptes ondatrae* is an ectoparasite that has invaded Europe by grasping the fur of muskrats (Bauer and Whitaker 1981, Šefrová and Laštůvka 2005, Whitaker 2007). Other species belong to the super-family **Acaroidea** and families Epidermoptidae and Pyroglyphidae. Epidermoptidae are skin parasites of birds. *Epidermoptes bilobatus* causes avian scabies. Pyroglyphidae are external parasites living on bird feathers or are nidicolous. *Dermatophagoides evansi* feeds on human detritus, and lives in house dust as well as within bird nests (Piotrowski 1990, Razowski 1997).

Among the super-order **Parasitiformes (Anactinotrichida)**, aliens belong to orders **Ixodida** and **Mesostigmata**. Ixodida is represented by the species in the family Ixodidae, which is treated in a separate section at the end of the chapter. Alien Mesostigmata belong to superfamilies **Ascoidea** and **Dermanyssoidea**. The first superfamily is represented by a single family with aliens, Phytoseiidae, which are predators of spider mites. In Europe, species such as *Phytoseiulus persimilis, Amblyseius* (*Neoseiulus*) *californicus* and *Iphesius* (*Amblyseius*) *degenerans* are used as biological control agents against phytophagous pests (Bartlett 1992, Croft et al. 1998, Easterbrook 1996, EPPO 2002, Garcia Mari and Gonzalez-Zamora 1999, Helle and Sabelis 1985, McMurtry and Croft 1997). Three families of Dermanyssoidea contain alien species. Varroidae mites are ectoparasites of honeybees. *Varroa destructor* is at present the most important parasite of *Apis mellifera* (L.). *Varroa* feeds on the haemolymph of adult, larval and pupal bees. Laelapidae mites live in soil, are nidicoles or parasitize small mammals and insects. *Ondatralaelaps multispinosus* is an ectoparasite of muskrats (Šefrová and Laštůvka 2005). *Laelaps echidninus is* a common worldwide ectoparasite of spiny rats, wild brown rats and is occasionally found on the house mouse and cotton rat (Wharton and Hansell 1957). Macronyssidae mites are haematophagous, have a large dorsal shield, prominent chelicerae and inconspicuous body setae (Easterbrook et al. 2008). *Ornithonyssus bacoti* is a parasite of rats, living in rat nests and their surroundings (Cole et al. 2005, Easterbrook et al. 2008, Fan and Petit 1998, Whitaker 2007). *Ornithonyssus bursa* is a natural parasite of common birds including pigeons, starlings, sparrows, Indian mynahs, poultry, and some wild birds, such as the robin (Berggren 2005).

7.4.3 Temporal trends of introduction in Europe of alien mite species

The rate of arrival of alien mites in Europe is increasing exponentially (Figure 7.4.2). An average of 2.1 alien species was newly recorded per year in Europe during 2000–2007 whereas only half this number was recorded during the period 1950–1974 (1 species/year). However, large differences were found between families.

The first records for Europe of all alien Tetranychidae are extensively documented in this chapter. There are no records reported before 1950; however, only few taxonomists were specialized on the family before this date. Since the second half of the 20th century, tetranychid species have been reported at an average rate of one new species every two years, with an acceleration of reports (one species per year) since 2000.

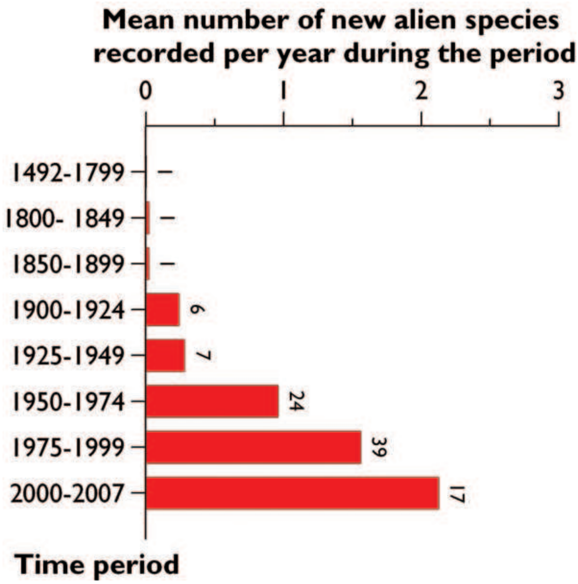

Figure 7.4.2. Temporal changes in the mean number of records per year of mite species alien *to* Europe from 1800 to 2009. The number over each bar indicates the absolute number of species newly recorded per time period.

Most of these mites represent agricultural pests, and therefore have been widely studied which explains the overrepresentation of crop pest species as Tetranychidae aliens.

The mean number of records of Eriophyoidae species alien to Europe increased rapidly during the third quarter of the 20th century. Only one species *Aceria alpestris*, which is alien in Europe, was recorded within the period 1850–1899. This species was described from the host plant *Rhododendron ferrugineum* L. from Tirol (Austria). The species was later recorded in mainland Italy, Czech Republic, Slovenia and Serbia, but it is not clear if it was associated with cultivated *Rhododendron*. Species recorded intensively between 1900–1924 (although described from Germany in 1857) are categorized as cryptogenic (*Eriophyes pyri,* the pear blister mite) or alien in Europe, like *Aculus hippocastani* (recorded in 1907, but probably introduced in Europe from the 17th century when its host plant *Aesculus hippocastanum* L. was intensively cultivated), and *Aceria loewi* (probably introduced in the 16th century when lilac started to be cultivated in France). *Aculops allotrichus*, which is alien to Europe, was recorded in 1912 but was probably, introduced with its host *Robinia pseudoacacia* L. which was for the first time introduced into France at the beginning of 17th century. *Aceria erinea* and *A. tristriata* were suspected to have an Asian origin and have been designated as aliens. They were recorded on 1903, but probably were present on its host, Persian walnut, in the Balkans and South Europe much earlier. Only one species in the Eriophyoidae was recorded between 1925–1949, e.g. *Aceria petanovicae,* the lilac rust mite. Being for long time known under the name of *Aculops massalongoi* the species is alien in Europe.

Six alien species to Europe were recorded between 1950–1974. Two pests of citrus, *Aceria sheldoni* (citrus bud mite) and *Aculops pelekassi* (citrus rust mite) and the azalea mite *Phyllocoptes azaleae*, are suspected to have been introduced from Asia. Characteristic symptoms of deformed lemon fruits caused by *A. sheldoni* were drawn by Battista Ferrari in Italy in 1664 (Ragusa 2002). Three pests have been reported from North American maple trees (*Acer negundo* L., *A. saccharinum* L. and *A. rubrum* L.), i.e. *Shevtchenkella brevisetosa, Vasates quadripedes* and *Rhyncaphytoptus negundivagrans*. The 25 species recorded during the period 1975–1999 almost all have a North American origin (only *Epitrimerus cupressi* is designated as cryptogenic, because of the Mediterranean origin of its host *Cupressus sempervirens* L.). During the period from 2000 to 2007, one species alien *to* Europe, *Rhyncaphytoptus bagdasariani,* has been recorded as being introduced from Asia and the serious pest *Aceria fuchsiae* (a species on the European quarantine list) was introduced from South America. As for other phytophagous mites, the most probable explanation for the acceleration in the pace of introductions of alien eriophyids is intensification of international trade. Most of these alien species inhabit ornamental trees and shrubs, flowers and potted ornamental plants.

Some alien parasitic mites have invaded Europe with rodents such as muskrats and brown rats. The muskrat (*Ondatra zibethicus* L.) is an invasive rodent native to North America. It was introduced around 1905, by humans as a fur resource in several parts of Europe, as well as in Asia and South America. Six species of mites, native from North America (Bauer and Whitaker 1981, Whitaker 2007), have invaded Europe grasping its fur (Glavendekić et al. 2005, Šefrová and Laštůvka 2005). The first report of muskrat mites was recorded in 1955, and a second in 2000, both in Czech Republic. Two other parasitic species, *Laelaps echidninus* and *Ornithonyssus bacoti*, are also alien ectoparasites of rodents that have invaded Europe and were identified in the 1950's (Šefrová and Laštůvka 2005), but the exact pathway of introduction is not known. One possible vector is the wild brown rat, *Rattus norvegicus* (Berkenhout). Thought to have originated in northern China, this rodent spread in Europe in the middle ages and is now the dominant rat in the continent.

Birds are vectors of a second group of alien parasitic mites, that include *Epidermoptes bilobatus* and *Ornithonyssus bursa*, both identified in the 1950's, in the Czech Republic (Šefrová and Laštůvka 2005). The exact route of introduction is not known with confidence, but a possible vector is the chicken (*Gallus gallus domesticus* L.). In the 20thcentury, with the intensifications of poultry production, concerns have been raised about the increasing risk of transfer of diseases and mites (from chickens to native bird species).

Whereas the exact date of arrival of alien mites is generally unknown, deliberately released biological control agents are the exception to this rule. Among them, three phytoseiids are mainly used as predatory species against pests (McMurtry and Croft 1997). *Phytoseiulus persimilis* was introduced for the first time in the 1970's in Bulgaria and Czech Republic (EPPO 2002, Šefrová and Laštůvka 2005). *Neoseiulus californicus* was introduced for the first time in 1991 in Great Britain (EPPO 2002). It was also introduced at the same period in the Czech Republic (EPPO 2002, Šefrová and Laštůvka

2005). The third introduced mite is *Iphiseius degenerans*. It is native from the Mediterranean region and was introduced for the first time in 1993 in Czech Republic (EPPO 2002, Šefrová and Laštůvka 2005). Nowadays, these three biological agents have been introduced in most European countries.

7.4.4 Biogeographic patterns of the mite species alien to Europe

7.4.4.1 Origin of the mite species alien to Europe

Figure 7.4.3. presents the region of origin of the 101 alien species of mites. Most of the alien mite species (52%) came from North America, then from Asia (25%), and Central and South America (10%). The origin of phytophagous alien mites can usually be inferred from the origin of the host plant. These mites are dispersed over long distances mainly by the introduction of plant material and spread further by plant cultivation in newly colonized regions. Aerial distribution is possible and most frequent, but mainly over short distances (Margolies 1993, Margolies 1995). In the case of highly polyphagous species such as several Tetranychidae, their ubiquity and highly diverse host uses might be misleading and the origin can be difficult to ascertain. Twelve out of 27 alien Tetranychidae originated in North America, nine in Asia and only five in Central and South America. Temperate regions provide the majority of the alien species (16 vs. 11 for tropical areas).

The majority of eriophyoid species are mono- or oligophagous and are distributed within the host range. North America appears to be the dominant source of the alien eriophyoid fauna with half of the species originating from this continent. Around 26% of species originate from Asia, and less than 10% from South America. A few species are designated as cryptogenic or with questionable origin. For example, *Rhyncaphytoptus negundivagrans,* although described from Hungary, probably originated from North America with its host plant, *Acer negundo*. Whereas the camellia rust mite, *Cosetacus cameliae* (described from California) was probably introduced to Europe from the USA, it probably has an Asian origin considering that *Camelia japonica* L. comes from subtropical and tropical regions of Southeast Asia. The pouch gall mite of plum leaves, *Eriophyes emarginatae,* first discovered in the USA, has also been recorded in Serbia and Japan. This mite is very closely related to the European *E. padi* (Nalepa) (Petanović 1997) and may even be the same species, with synonymous names (Keifer 1975). *Epitrimerus cupressi* was described from North America, but according to the origin of its host plant *Cupressus sempervirens*, which is from the Mediterranean region, the mite probably has an European origin too. The gall mite *Phytoptus hedericola* (Phytoptidae) is native from South Africa (Glavendekić et al. 2005), and *Trisetacus chamaecypari* (Phytoptidae) from North America (Ostojá-starzewski and Halstead 2006, Smith et al. 2007).

Among the false spider mites (Tenuipalpidae), *Brevipalpus californicus, B. obovatus* and *Tenuipalpus pacificus* originated from Central and South America, and Florida

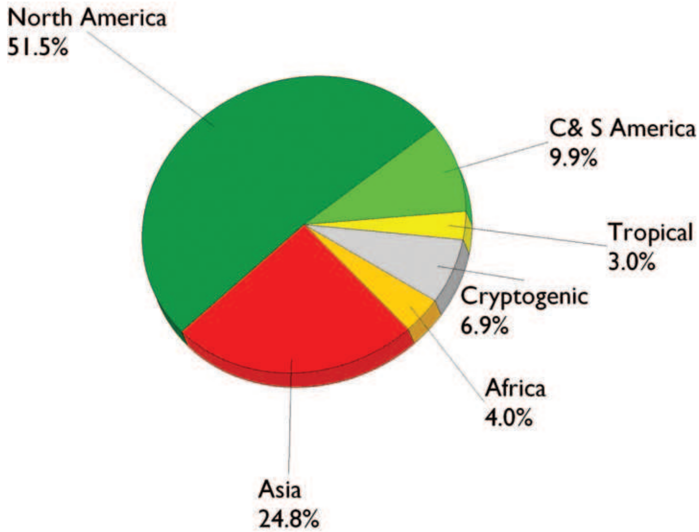

Figure 7.4.3. Origin of the mite species alien *to* Europe.

(USA) (Denmark 1968, Manson 1967). Six alien species of rodents bear parasitic mites originating from North America, and belong to the families Listophoridae (four species), Laelapidae (one species), and Myocoptidae (one species). In their native country, they are all ectoparasites of murskrats. There are also some bird parasites: one species of Epidermoptidae, *Epidermoptes bilobatus*, is an ectoparasite native from South Asia, and *Ornithonyssus bursa* is probably native from Trinidad.

A single *Varroa* species, *V. destructor,* is alien to Europe (Griffiths and Bowman 1981). Its native range is South East Asia, where it was originally confined on its original host, the Asian honeybee, *Apis cerana* F. This mite came to be a parasite of the European honeybee, *Apis mellifera,* in the mid-twentieth century. Importation of commercial *A. mellifera* colonies into areas with *A. cerana* brought the previously allopatric bee species into contact and allowed *V. destructor* to switch to the new host

7.4.4.2 Distribution in Europe of the alien mite species

Alien mite species are not evenly distributed throughout Europe. Large differences in the number of aliens are noticed between countries (Figure 7.4.4) but it may reflect differences in sampling efforts and in the number of local taxonomic specialists.

Among the Tetranychidae, 19 alien species are found around the Mediterranean Basin and 12 in the rest of Europe. With relatively warm winters, the Mediterranean region provides suitable climatic living conditions for many species of temperate climates, but also for the establishment of many species of tropical or sub-tropical origin. Except for *Panonychus citri* and the cryptic species *Tetranychus ludeni*, which can be found in glasshouses in Europe, all tropical alien spider mites are restricted to the area around the Mediterranean Sea.

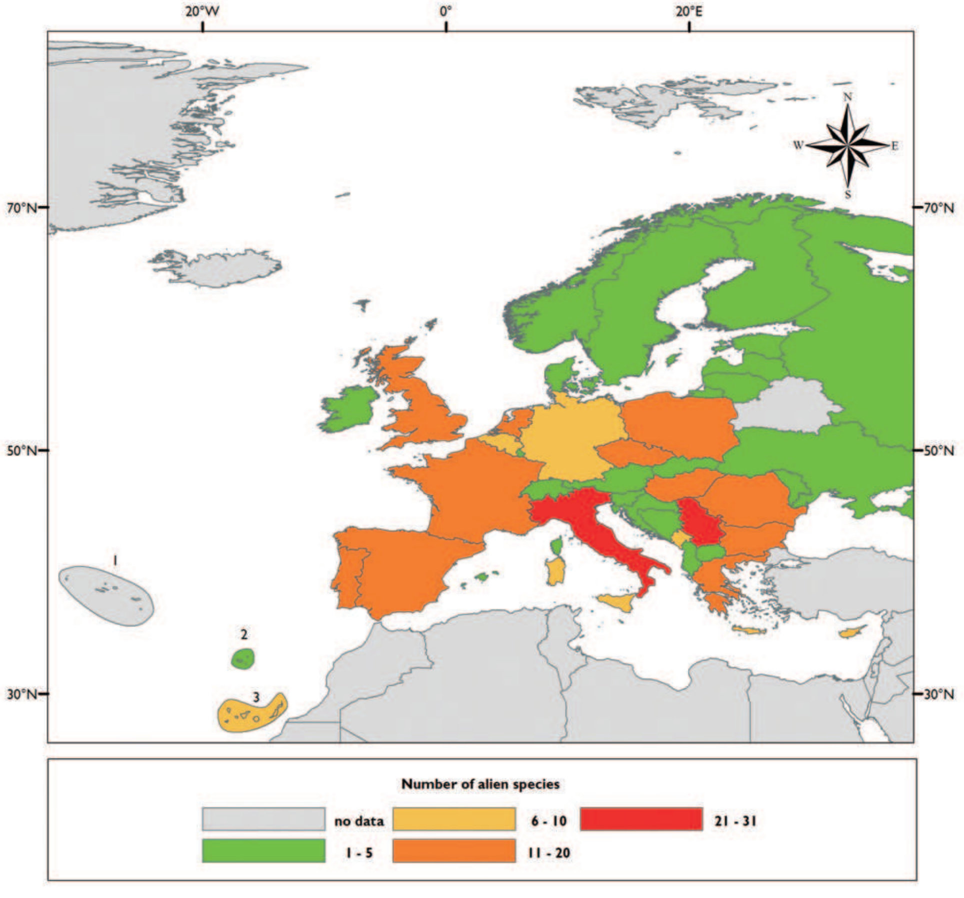

Figure 7.4.4. Comparative colonization of continental European countries and islands by mite species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary Islands.

Most alien Eriophyids have a very restricted distribution. More than 40% of the species have been observed in only one country (17 species), more than 40% (21 species) in 2–5 countries, and approximately 20% (7 species) in 6–11 countries. Eight European countries have no recorded occurrence of alien eriophyoids to date. Only one species, the pear blister mite *Eriophyes pyri* (which has cryptogenic status), has been recorded from 32 European countries. Besides *E. pyri,* the more widely distributed eriophyoid species are: *Aceria erinea, A. loewi, A. sheldoni, Aculops pelekassi* and *Eriophyes canestrini.* The gall mite *Phytoptus hedericola* (Phytoptidae) entered Europe in 2002 and has been observed in Serbia (Glavendekić et al. 2005). *Trisetacus chamaecypari* (Phytoptidae) entered Europe in 2002 (Ostojá-starzewski and Halstead 2006, Smith et al. 2007). The status of *Typhloctonus squamiger* (Phytoseiidae), a poorly known phytophagous mite found on trees in Italy since 1991 (Rigamonti and Lozzia 1999), is questionable.

The distribution of biological agents belonging to the Phytoseiidae family is well-known. *Phytoseiulus persimilis* is now present in nearly all of Europe (Table 7.4.1)

(EPPO 2002). *Neoseiulus californicus* has been found in the same countries except Austria, Hungary, Morocco, Slovakia, Sweden and Turkey. The third introduced phytoseid mite, *Iphesius degenerans*, is also present in several countries (Table 7.4.1).

The broad mite *Polyphagotarsonemus latus* (Tarsonemidae) is now cosmopolitan. In Europe, it was reported for the first time in 1961 and since then the mite has invaded almost all countries (Table 7.4.1) (CAB-International 1986, Fan and Petit 1998, Natarajan 1988, Parker and Gerson 1994); it is potentially now in all parts of Europe.

Three species of false spider mites (Tenuipalpidae) are major invaders in Europe. *Brevipalpus californicus*, found in 316 orchid and tree species of 67 genera and 33 families, was first recorded in 1960 and is mainly observed in citrus trees around the Mediterranean basin (Denmark 1968, Manson 1967). The privet mite, *Brevipalpus obovatus* is found in 451 herb, ornamental and shrub species (19 genera, 55 families) (Manson 1967) has been recorded from Austria, Cyprus, France, Germany, Israel, Netherlands, Serbia and Spain (Manson 1967). *Tenuipalpus pacificus* (the Phalaenopsis mite) is found in greenhouses of *Phalaenopsis* orchids in Germany, Great Britain, Netherlands and Serbia (Denmark 1968, Manson 1967).

The introduced range of *Varroa destructor* is practically worldwide. It was first reported in Eastern Europe in the mid- 1960s and it has spread rapidly all over the continent. Two different genotypes, characterized by mitochondrial DNA sequences, have spread as independent clonal populations (Solignac et al. 2005), the Korean and the Japanese haplotypes, the latter having been found, besides Asia, in the Americas only.

7.4.5. Pathways of introduction in Europe of alien mite species

Although colonisation routes are poorly documented for the Tetranychidae, it is known that many species travel with their host plant. Small organisms like tetranychids are easily transported with plant material (leaves and in bark crevices). Only five species feed mainly on herbaceous plants (*Tetranychus evansi*, *T. macfarleni*, *T. sinhai*, *Schizotetranychus parasemus*, and *Petrobia lupini*), whereas all other alien species in the family feed on perennial shrubs.

As for tetranychids, the horticultural and ornamental trade is probably the most important factor for accidental introductions of almost all species of alien Eriophyoidae. Just a few species of Eriophyoids are on European quarantine lists, as plants are rarely inspected for presence of these mites. Infested plant material is not regularly intercepted at borders even in the case of important pests such as the grape rust mite *Calepitrimerus vitis* (Nalepa) or the blackberry fruit mite *Acalitus essigi* (Hassan), which are frequently disseminated with plant seedlings. During recent decades more than 50% of aliens were imported with ornamental plants. Among eriophyids, which are obligate plant parasites, only one trophic group which is associated with weeds, can be subject to intentional introduction. Although these mites were recently nominated as potential agents for classical biological control of weeds (few species are imported for this purpose), they have not yet been used for this purpose in Europe. Four species of alien eriophyoids which were probably introduced along with their host plants may have the potential as biological control agents of serious alien weed pests. In particular, *Aceria ambrosiae* can be used against the allergenous weed *Ambrosia artemisifolia* L. that was imported into Europe from North America.

As for other phytophagous species, the broad mite *Polyphagotarsonemus latus* (Tarsonemidae) has mainly been dispersed by human activities, but also by wind or insect transfer. Movement by insects should not be neglected: this concerns almost only females that get attached to the legs of aphids and the whiteflies *Bemisia argentifolii* (Bellows and Perring), *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae) (Fan and Petit 1998, Natarajan 1988, Parker and Gerson 1994).

Although including important crop pest species, the dispersal potential of false spider mites (*Brevipalpus* spp.), Tenuipalpidae, remains unclear (Childers et al. 2003a, 2003b).

Intentional introductions of mites represent a low proportion of alien arrivals. Only three phytoseeid predators were introduced purposely for biological control and have established. Some of these biological control agents were released in the field but others were first released in glasshouses, and then escaped and became established outdoors.

International travel and commerce has facilitated the dispersal of *Varroa destructor*. Once established in a new region, the mite spreads using drifting, robbing, and swarming behaviour of the host. Human mediated varroa dispersion also occurs via apicultural practices.

7.4.6. Ecosystems and habitats invaded in Europe by alien mite species

Alien mites established in Europe predominantly live in agrosystems or anthropogenic environments (ca. 92%; Figure 7.4.5). This is especially verified in Tetranychidae and Eriophyidae. Among eriophyoids, some are present in man-made habitats, parks and gardens (22 species), agricultural lands (13 species), and greenhouses (10 species); very few species inhabit woodland and forest, costal, alpine or sub alpine habitats. Most alien species in this superfamily are leaf vagrants (13 species). Twelve species cause leaf galls, *erinea** and leaf rolling, 11 cause leaf and/or fruit russeting or other type of discolouration, six live predominantly in buds causing bud galls, three species cause stunting of whole plants and/or plant organs and two cause flower and/or fruit deformations. Among the leaf gall makers, the most important horticultural pests are distributed in many European countries, such as *E. pyri, A. erinea, A. tristriata* or, such as *A. fuchsiae* which is on quarantine lists. Among the rust mites, only a few are important horticultural pests like *A. theae, A. pelekassi* and *C. carinatus.* Most species are pests of ornamental trees, shrubs or flowering plants, having an important aesthetic impact on plants in parks and streets in most European towns and cities (i.e. *A. gleditsiae, A.ligustri, A. petanovicae, S. strobicus, P. chrysanthemi*), an exception being *A. sawatch-*

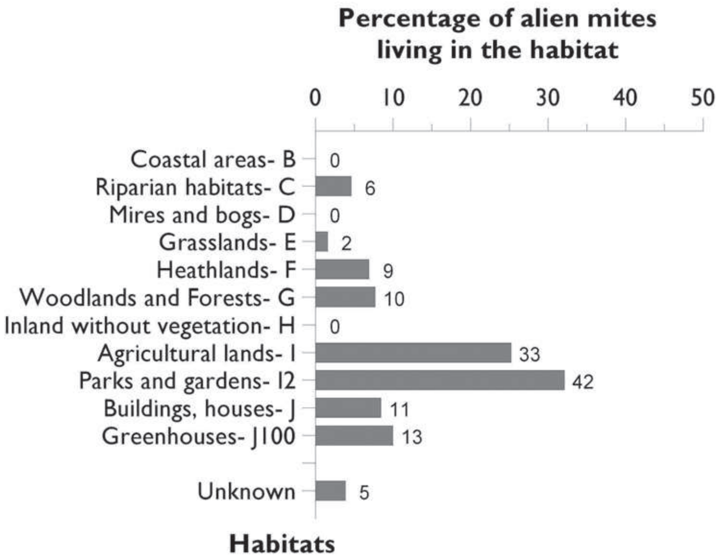

Figure 7.4.5. Main European habitats colonized by the established alien species of mites. The number over each bar indicates the absolute number of alien dipterans recorded per habitat. Note that a species may have colonized several habitats.

ensae which inhabits weeds. Two Eriophyoids which cause plant stunting, *A. paradianthi* and *T. califraxini,* are important pests of ornamental plants and one species, *A. ambrosiae,* is a potential biocontrol agent against the alien weed *Ambrosia artemisifolia.* Two species which cause flower and/or fruit deformations, *A. alpestris* and *A. sheldoni,* are respectively pests of *Rhododendron* and citrus trees.

The gall mite *Phytoptus hedericola* lives on ivy (*Hedera helix* L.) and *Trisetacus laricis* switched from American larch to European larch (*Larix decidua* Mill.).

The broad mite *Polyphagotarsonemus latus* (Tarsonemidae) has a very short life cycle of a few days, damaging crops abruptly. Being highly polyphagous, the species has been reported on 57 plant families (Gerson 1992) both in open field crops and in greenhouses. This is an important pest of crops and ornamental plants such as azaleas, castor bean, chillies, citrus fruits, cotton, cucumber, mango, papaya, pepper, potato, sweet potato, tea, tomato and winged bean (Gerson 1992, Glavendekić et al. 2005, Heungens 1986, Raemaekers 2001). Nevertheless, in Europe this mite is found mainly in greenhouses because the mite cannot survive winter conditions outdoors.

False spider mites (*Brevipalpus* spp.; Tenuipalpidae) present a risk of invasion in greenhouses. *Brevipalpus obovatus* (the privet mite) is found on ornamentals and shrubs like citrus and azaleas and could become of great importance in glasshouses for ornamentals (Childers et al. 2003a, 2003b). *Tenuipalpus pacificus* (the Phalaenopsis mite) is one of the rare monophagous mites in the family, but it is a very destructive pest of orchids under greenhouses, mainly because it has several generations per year and has a two-month life cycle (Denmark 1968, Manson 1967).

A Pyroglyphidae mite, *Dermatophagoides evansi*, is a cosmopolitan free-living species, often encountered in synanthropic situations and has probably been accidentally introduced by humans (Bigliocchi and Maroli 1995, Hughes 1976).

7.4.7. Ecological and economic impact of alien mite species

Seven species of alien Tetranychidae are important pests. On citrus, four alien species are found: *Panonychus citri*, *Eotetranychus lewisi* (also on grapes) *Eutetranychus banksi* and *E. orientalis,* the last presently spreading to Southern Portugal and Spain from Huelva to Murcia and Alicante. *Oligonychus perseae* is found on avocado and produces very severe damage in southern Spain (Malaga, Granada and Huelva) and in the Canary Islands. *Stigmaeopsis celarius* is found on bamboos and causes important visual damage to these ornamental plants. *Tetranychus evansi* is found on solanaceous crops and can reach very high density as observed in France, Spain and Canary Islands. All these mites are present in the Mediterranean Basin, which appears to be the region most threatened by alien species. Only two of these species can be found outside the Mediterranean area: *Panonychus citri*, especially in glass-houses, and *Stigmaeopsis celarius*.

In humid citrus-growing regions of the world, eriophyoid mites are considered to be the major mite pests (Jeppson et al. 1975, McCoy 1996). Two alien species, *Aceria sheldoni* and *Aculops pelekassi*, distributed worldwide, are among the most important pests infesting citrus. The pear blister mite, *Eriophyes pyri,* widely distributed in Europe, probably does little harm to the tree, but in severe infestations, the tree leaves may become disfigured, and most importantly the mite may damage fruits (Easterbrook et al. 2008). Besides fruit orchards, species in the superfamily inhabiting wild trees in natural forests are: *Aceria tristriata* and *A. erinea* which appear to be the most common and most injurious eriophyoids found on *Juglans regia* L. (Castagnoli and Oldfield 1996). Among the five species of eriophyoid mites reported from commercially important beverage crops in different parts of the world, wherever tea is grown, the purple tea mite *Calacarus carinatus* and the pink tea mite *Acaphylla theae* are economically important in Southeast Asian countries, and in India (Channabasavanna 1996). Both species are aliens to Europe, reported from mainland Italy (*A. theae*) and from Hungary, Poland and Spain (*C. carinatus*). Records concerning host plant range in the case of *C. carinatus* are, besides tea, *Viburnum opulus* L. and *Capsicum annuum* L. (Amrine and Stasny 1994). Bearing in mind that congeneric *Calacarus citrifolii* has an extremely wide host range (Oldfield 1996), this might be also the case for *C. carinatus,* which would convey on the latter serious pest status in Europe. Economic impact of alien pest species of eriophyoids on ornamentals has been observed for *Aculops gleditsiae* on honey locust, *Aceria petanovicie* on lilac, *Aculops ligustri* on privet hedges, *Aculops allotrichus* on black locust, *Reckella celtis* on *Celtis australis* L., *Shevtchenkella brevisetosa* on *Acer negundo, Vasates quadripes* on silver maple, *Phytoptus hederae* on English ivy, and *Setoptus strobicus* on *Pinus strobus* L. (Petanović 2004). Flower and foliage aesthetic impact has been observed indoors (business centers, restaurants, shopping centers, hotels, etc.) for a few alien eriophyoids, *Cecidophyopsis hendersoni* causing a powdery

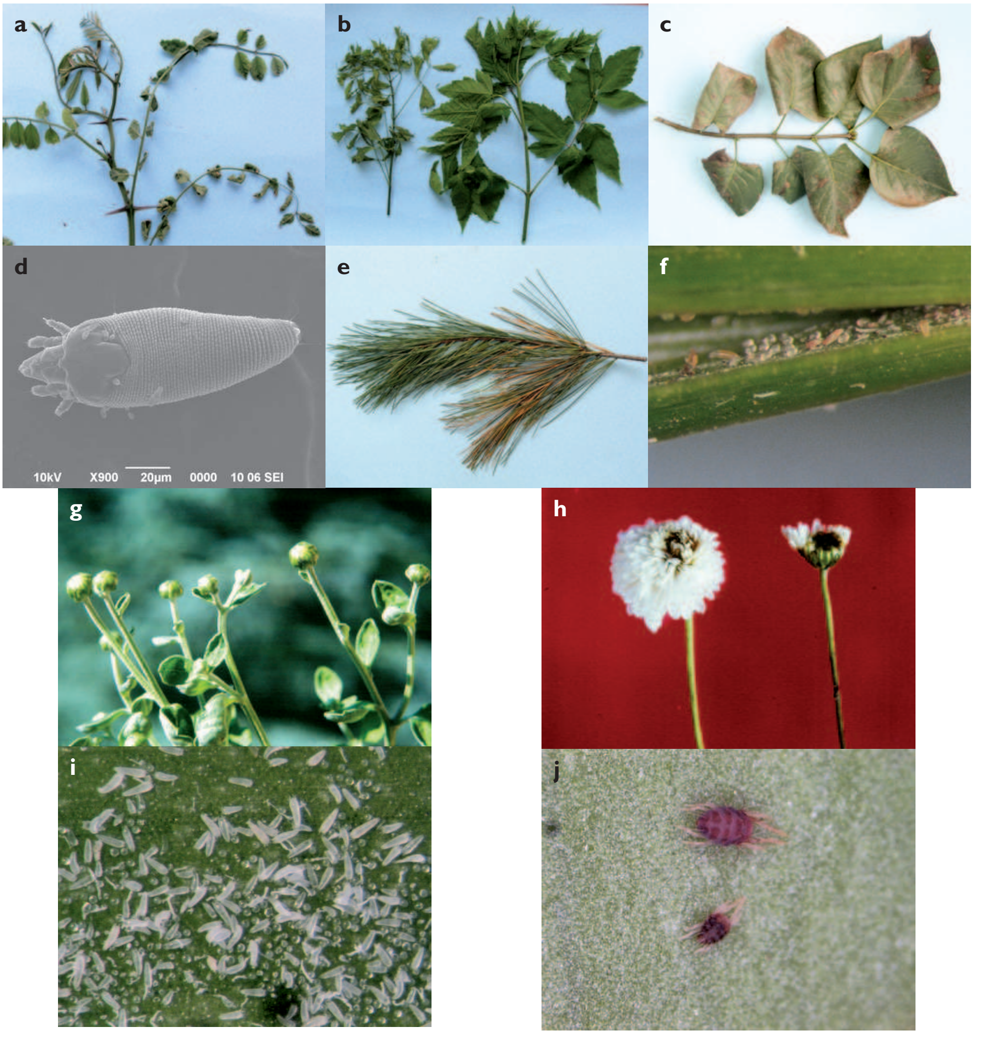

Figure 7.4.6. Alien mites and their damage. **a** Curling and rusting of black locust leaves caused by *Aculops allotrichus* **b** Chlorotic and misshapen leaves of *Acer negundo* caused by *Shevtchenkella brevisetosa* (left) and uninfested leaves (right) **c** Leaf rusting of lilac leaves caused by *Aceria petanovicae* **d** *Aceria petanovicae*, dorsal view-SEM photograph **e** Rusting of *Pinus strobus* needles caused by *Setoptus strobacus* **f** *Setoptus strobacus* eggs, juveniles and adults between needles of *Pinus strobus* **g** Leaf distortion and unopened damaged flower buds of chrysanthemum caused by *Paraphytoptus chrysanthemi* **h** Deformed flower heads of chrysanthemum caused by *Paraphytoptus chrysanthemi* **i** Colony of *Cecidophyopsis hendersoni* on *Yucca* leaf **j** *Panonychus citri*. (**a–i** Credit: Radmila Petanović; **j** Credit: Alain Migeon).

appearance on *Yucca* leaves, *Cosetacus cameliae* causing bud rust and abortion on flower buds of *Camelia* plants, and *Paraphytoptus chrysanthemi* causing deformed buds, hairy leaves and rust on *Chrysanthemum* (Petanović 2004).

The broad mite *Polyphagotarsonemus latus* (Tarsonemidae) and the false spider mites (*Brevipalpus* spp.) (Tenuipalpidae) are major pests of great agronomical importance because of their broad host range, worldwide distribution and economic impact (CAB-International 1986, Fan and Petit 1998, Gerson 1992, Heungens 1986, Natarajan 1988, Parker and Gerson 1994, Raemaekers 2001). The most important threat for *Brevipalpus* spp. is the spread of citrus viruses (Childers et al. 2003b).

Among parasitic mites, the hair mites (muskrat mites) are currently considered non-pathogenic for humans although they are sometimes found in the fur of other mammals. *Laelaps echidninus* (Laelapidae) is a common worldwide ectoparasite of the spiny rats (hystricognath rodents), wild brown rat and is occasionally found on the house mouse, cotton rat and other rodents. It is a bloodsucking mite and the natural vector of *Hepatozoon muris* Balf. (Protozoa, Adeleidae), a haemogregarine parasite pathogenic for white rats (Smith et al. 2007) but which should not be overlooked as a possible vector of disease to humans (Wharton and Hansell 1957). *Ornithonyssus bacoti* (Macronyssidae) is a parasite of rats and inhabits the area in and around the rat's nesting area. This mite is the only one of the common rat mites which frequently deserts domestic rats to bite man or his domestic and laboratory animals (Cole et al. 2005). It is also a bloodsucking mite and its bite is painful and causes skin irritation, itching and skin dermatitis in humans (James 2005). *Ornithonyssus bacoti,* is a known vector of the murine filarial nematode *Litomosoides carinii* Travasaos. In addition, it is susceptible to the transmission of endemic typhus, *Rickettsia typhi* (Wolbach and Todd) 1943 (= *R. mooseri* Monteiro) to humans (Berggren 2005, Bowman et al. 2003).

Epidermoptes bilobatus (Epidermoptidae) is a bird parasite causing avian scabies. This endoparasite burrows into the skin causing inflammation and itchiness. The skin thickens with brownish-yellow scabs, which may become secondarily infected with a fungus. It is difficult to control and can cause death. Culling infested birds is usually required (Department of the Environment and Heritage 2006). *Ornithonyssus bursa* (Macronyssidae) is an haematophagous natural parasite of common birds including pigeons, starlings, sparrows, Indian mynahs, poultry, robin (Berggren 2005). These pest mites and parasites are and will remain a long term problem for poultry housing (Gjelstrup and Møller 1985). Although none of these two species of mites are truly parasitic on humans and pets, they readily bite humans and are liable to cause allergies and dermatitis in human (Denmark and Cromroy 2008, James 2005). *Dermatophagoides evansi* (Pyroglyphidae), and a species alien *in* Europe, *Glycyphagus domesticus* (Glycyphagidae), have been accidentally introduced by humans and often encountered in synanthropic situations (Bigliocchi and Maroli 1995, Hughes 1976, Thind and Clarke 2001). *Glycyphagus domesticus* also occurs in bird, bat and mammal nests. It is associated with moist and humid conditions that promote the growth of mould on which they feed (Thind and Clarke 2001). *Dermatophagoides evansi* (Pyroglyphidae) feeds on detritus and is also found in house dust, birds' nests and poultry houses (Piotrowski 1990, Razowski 1997). *Dermatophagoides evansi* represents a source of airborne allergens in indoor house dust (Eriksson 1990, Musken et al. 2000) that may cause sensitization, dermatitis, rhinopharyngitis and asthma especially among farmers.

The honeybee ectoparasite *Varroa destructor* causes serious losses through feeding injury in apiaries in Europe but also almost worldwide. While the populations of the

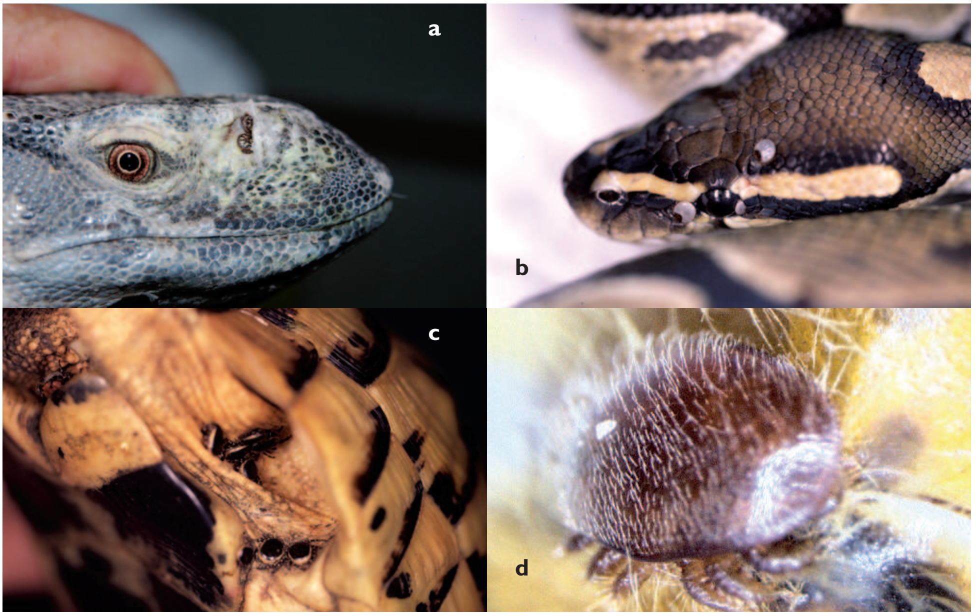

Figure 7.4.7. Ixodidae ticks on tortoises and snakes. **a** Hyalomma aegyptium on tortoise **b** Amblyomma exornatum semi-engorged on Python head **c** Amblyomma sp. on snake head (Credits: Nicasio Brotons) **d** Female of *Varroa destructor* on abdomen of *Apis mellifera* (Credit: Alain Migeon).

parasite reach only a small size within colonies of *A. cerana* and do not damage the colony, infested *A. mellifera* colonies die. The problems with varroa control are typical of those encountered in curbing arthropod pest population. Varroas are becoming resistant to the acaricides used by beekeepers to control them. The recent discovery in several parts of the world (notably the United States of America (Harbo and Harris 2005) and Europe (Le Conte et al. 2007)) of honeybee bee colonies able to tolerate heavy infestations of *V. destructor* opens the door to lasting solutions for controlling the parasite.

A positive impact is recognized for the three mite species deliberately introduced to Europe for biological control of house flies and tetranychid mites. *Phytoseiulus persimilis* and *N. californicus* are two well-known biological control agents used against spiders mites such as *Tetranychus urticae* Koch (Garcia Mari and Gonzalez-Zamora 1999, Helle and Sabelis 1985) and *Phytonemus pallidus* (Banks) (James 2005). The third introduced mite, *Iphiseius degenerans,* targets numerous species of thrips (van Houten and van Stratum 1993, van Houten and van Stratum 1995), e.g. *Thrips tabaci* Lindeman and *Frankliniella occidentalis* (Pergande) (Albajes et al. 1999, Bartlett 1992, McMurtry and Croft 1997, Sengonca et al. 2004).

7.4.8. Alien tick species: case studies

It is difficult to ascertain if a tick may have permanent populations outside of its native range or, to the contrary, they are just isolated records. In some cases, a few examples of a given species have been reported for a small area or found over non-resident hosts. This may result from the introduction of a few specimens, commonly immature stages. The most important means of introduction and expansion of ticks (provided that suitable climate and host is available) is by means of engorged females, because of their huge potential to lay thousands of eggs.

The movements of domestic ungulates have introduced some tick species, that may be considered to produce permanent and viable populations out of their native range. An example is the introduction of *Hyalomma dromedarii* into the Canary Islands, by the importation of dromedaries (*Camelus bactrianus* L.). The native range of this tick is northern Africa where *C. bactrianus* is the main adult host, and *H. dromedarii* is abundant in wide areas of Mauritania and Morocco. The current population of dromedaries in the Canary Islands was introduced from Morocco at the end of 18th Century, and it seems that this tick came into these islands using dromedary hosts. *H. dromedarii* may use a wide range of hosts in immature stages, thus increasing risk of spread and permanent establishment (Apanaskevich and Horak 2008, Apanaskevich et al. 2008). It is difficult, however, to assess the reliability of records of *Hyalomma anatolicum excavatum*. A recent review of the original two subspecies (*H. a. anatolicum* and *H. a. excavatum*), concluded that they should be considered as separate species, although the matter is hard to decide as both taxa have a well defined allopatric range (Apanaskevich 2003). *H. excavatum* is restricted to central and eastern Asia and *H. anatolicum* colonizes wide areas of northern Africa. The records of *H. excavatum* from Bulgaria, Albania, Greece, and Italy should be cautiously treated, as they may probably represent *H. anatolicum* imported from northern Africa with domestic ungulates, as is the case for *Hyalomma detritum*. The formerly recognized species *H. detritum*, restricted to northern Africa, is now considered to be a synonym of the European *H. scupense*, which occurs not only in scattered localities of mainland Europe but is present in wide areas of northern Africa. Similarly, caution should be also applied for the single record of *Hyalomma truncatum* in the Canary islands. This tick is currently known to be restricted to parts of Asia, while a close species, *H. rufipes*, is common in sub-saharan Africa. While the adults of *H. rufipes* feed on a variety of hosts, including domestic ungulates, the immature stages commonly attach to diverse passerine birds. Most of these birds perform long distance travel in their migratory flights from Africa to Europe, and they have been found carrying hundreds of immature ticks (Hoogstraal 1956). However, as mentioned above, it is difficult for a population of nymphs to produce a viable and permanent population of resident ticks. To our knowledge, *H. rufipes* has been recorded only in Cyprus and Macedonia (Apanaskevich and Horak 2008), and we still do not know if these are permanent populations or only accidental records on their passerine hosts on migration to lower latitudes from sub-saharan Africa.

The scenario for the tortoise tick, *Hyalomma aegyptium*, is however different. Its presence outside northern Africa has been reported in countries such as Romania, Spain, Italy, Greece, Bulgaria, Croatia, and even farther north in Belgium (Siroky Pet al. 2007). The tick has permanent populations in areas of southern Russia (Robbins et al. 1998). There have been also introductions of this tick by tortoises imported form northern Africa or eastern Europe, where this tick is common. The only record of a permanent population of *H. aegyptium* as a consequence of an accidental importation recorded for eastern Spain (Brotóns and Estrada-Peña 2004). Since the ticks attach to portions of the neck and legs of the host body, it may be difficult to find feeding stages even after careful observation of the hosts. In the reported case of introduction of several specimens of *Testudo graeca* infested by ticks, the hosts were kept in a large private garden with a Mediterranean-type climate and vegetation. After some years of recurrent tick parasitism in the tortoises without new importations and repeated treatments, it was realized that the tick had permanent populations in the garden, and the hosts became infested according to the seasonal activity of the ticks.

An interesting case of tick introduction into mainland Europa are ticks commonly found on snakes, like *Amblyomma latum* and *A. exornatum* (both formerly in the genus *Aponomma*). These ticks feed for a long period on the host, and owing to their small size and preference to feed under host scales, they are commonly unrecognized while importing a host out of its native range. *Amblyomma latum* is a very common parasite of *Python spp*., which is becoming increasingly popular as a pet in Europe. The only known case of an importation of *A. exornatum* was noticed on specimens of *Varanus niloticus* that arrived into Spain (Estrada-Peña (Unpubl.)). These imported ticks founded a permanent population in the terrarium where the lizards live, under suitable conditions of high relative humidity and controlled temperature.

A very peculiar case of tick introduction is an alien *in* Europe, the brown dog tick, *Rhipicephalus sanguineus*. While feeding on domestic dogs, this tick is endophilic and is normally restricted to the Mediterranean region, being abundant in kennels, human constructions and private gardens where dogs remain unprotected against tick bites. Because of its endophilic behaviour, this tick may survive independently of prevailing environmental conditions, since human habitations buffer harsh climate. Therefore, unprotected pets travelling may harbor feeding ticks, and introduce them to uninfested areas which might be far from their native range. Such cases of introduction have been commonly recorded in the United Kingdom and northern European countries (Garben et al. 1980, Sibomana et al. 1986), as well as in Czech Republic (Černý 1985). Although there are as yet no reports of its establishment outdoors, this tick could become established out of its former native range as a consequence of global warming.

References

Albajes R, Gullino ML, van Lenteren JC, Elad Y (1999) Biological control of thrips. In: *Integrated Pest and Disease Management in Greenhouse Crops*. The Netherlands: Springer. pp. 244–253.

Alcázar MD, Aranda G, Márquez AL, Sánchez L, Ruiz C (2005) *Oligonychus persea* (Acari: Tetranychidae); una nueva plaga en el aguacate en el Sur de España. *IV Congresso Nacional de Entomología Aplicada - X Jornadas Científicas de la SEEA - I Jornadas Portuguesas de Entomologia Aplicada*, Bragança - Portugal: 213.

Amrine JW Jr, Stasny TAH (1994) *Catalog of the Eriophyoidea* (*Acarina, Prostigmata*) *of the World*. West Bloomfield, Michigan: Indira Publishing House. 531 pp.

Anagnou-Veroniki M, Papaioannou-Souliotes P, Karanastasi E, Giannopolitis CN (2008) New records of plant pests and weeds. *Hellenic Plant Protection journ*al, 1: 55–78.

Apanaskevich DA (2003) Differentiation of closely related species *Hyalomma anatolicum* and *H. excavatum* (Acari, Ixodidae) based on a study of all life cycle stages, throughout their entire geographical range. *Parazitologiya* 37: 259–280.

Apanaskevich DA, Horak IG (2008) The genus *Hyalomma* Koch, 1844: V. Re-evaluation of the taxonomic rank of taxa comprising the *H.* (*Euhyalomma*) *marginatum* Koch complex of species (Acari: Ixodidae) with redescription of all parasitic stages and notes on biology. *International Journal of Acarology* 34: 13–42.

Apanaskevich DA, Santos-Silva M, Horak I (2008) The genus *Hyalomma*, Koch 1844. IV. Redescription of all parasitic stages of *H.* (*Euhyalomma*) *lusitanicum* Koch, 1844 and the adults of *H.* (*E.*) *franchinnii* Tonelli Rondelli, 1932 (Acari: Ixodidae) with a first description of its immature stages. *Folia Parasitologica* 55: 61–74.

Aucejo S, Foo M, Gimeno E, Gomez-Cadenas A, Monfort R, Obiol F, Prades E, Ramis M, Ripolles JL, Tirado V, Zaragoza L, Jacas JA, Martinez-Ferrer MT (2003) Management of *Tetranychus urticae* in citrus in Spain: acarofauna associated to weeds. *Bulletin OILB/SROP* 26: 213–220.

Auger P, Migeon A (2007) Les tétranyques des bambous en France. *PHM Revue Horticole* 488: 17–19.

Balevski A (1967) [Tetranychid mites occuring on fruit crops] (in Bulgarian). *Izvestija na Instituta za Zastita na Rastenijata*, *Gara Kostinbrod*: 157.

Bartlett PW (1992) Experience of polyphagous pests of protected crops in Great Britain. *EPPO Bulletin* 22: 337–346.

Battelli C, Catteruccia G, Sobrero L (1977) *Hyalomma excavatum* Koch in Italia. *Atti Societá italiana di Scienze veterinarie* 31: 741–743.

Bauer CA, Whitaker JOJ (1981) Ectoparasites of muskrats from indiana with special emphasis on spatial distribution of coexisting mites of the genus *Listrophorus*. *American Midland Naturalist* 105: 112–123.

Bebić N (1955) [Pests in Kosmet during 1953 and 1954] (in Serbian). *Plant protection*, 30: 85–91.

Berggren Å (2005) Effect of the blood-sucking mite *Ornithonyssus bursa* on chick growth and fledging age in the North Island robin. *New Zealand Journal of Ecology* 29: 2430–2500.

Bernini F, Castagnoli M, Nannelli R (1995) Arachnida Acari. In Minelli A, Ruffo S, La Posta S (Eds) *Checklist delle specie della fauna italiana, 24*. Bologna: Calderini, 24–66.

Bigliocchi F, Maroli M (1995) Distribution and abundance of house-dust mites (Acarina: Pyroglyphidae) in Rome, Italy. *Aerobiologia* 11: 35–40.

Boczek J (1964) Studies on mites (Acarina) living on plants in Poland. IV *Bulletin de l'Académie des Sciences Polonaises* 12: 365–369.

Boczek J, Kropczynska D (1964) Studies on mites (Acarina) living on plants in Poland I. *Fragmenta Faunistica Warszawa* 11: 161–188.

Bolland HR, Gutierrez J, Flechtmann CHW (1998) *World catalogue of the spider mite family* (*Acari: Tetranychidae*). Leiden: Brill Academic Publishers. 392 pp.

Bowman CE, Bartlett PW (1978). *Panonychus citri* (McGregor) (Acari: Tetranychidae) infesting imported Citrus mitis in England. *Plant Pathology* 27: 201.

Bowman DD, Lynn RC, Eberhard ML (2003) *Georgi's Parasitology for Veterinarians*. 8.ed. St. Louis: Saunders. 422p.

Bozai J (1970) Determination key for spider mites. *Növényvédelen* (*Plant protection*) 10: 455–460

Bozai J (1974) Contributions to the knowledge of the Tetranychoid fauna of Hungary (Acari). *Folia Entomologica Hungarica* 27: 5–7.

Brotóns NJ, Estrada-Peña A (2004) Survival of tick colonies on captive imported reptiles in Spain. In *Abstracts of the 7th International Symposium on pathology and medicine of reptiles and amphibians*. Berlin, Germany.

CAB-International (1986) *Distribution maps of plant pests*. Wallingford, UK.

Carmona MM (1992) Acaros fitofagos e predadores da Ilha da Madeira – II. *Boletín de Sanidad Vegetal, Plagas* 18: 469–482.

Castagnoli M, Oldfield GN (1996) Other Fruit Trees and Nut Trees. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 543–559.

Castagnoli M, Nannelli R, Simoni S (2006) Un nuovo temibile fitofago per la fauna italiana: *Tetranychus evansi* (Baker e Pritchard) (Acari Tetranychidae). *Informatore Fitopatologico* 2006: 50–52.

Černý V (1985) First case of introduction of the tick *Rhipicephalus sanguineus* to Czechoslovakia. *Folia Parasitologica* 32: 162.

Channabasavanna GP (1996) Sugarcane, coffee and tea. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 631–640.

Childers CC, French JV, Rodrigues JCV (2003). *Brevipalpus californicus, B. obovatus, B. phoenicis,* and *B. lewisi* (Acari: Tenuipalpidae): a review of their biology, feeding injury and economic importance. *Experimental and Applied Acarology* 30: 5–28.

Childers CC, Rodrigues JCV, Welbourn WC (2003) Host plants of *Brevipalpus californicus, B. obovatus,* and *B. phoenicis* (Acari: Tenuipalpidae) and their potential involvement in the spread of one or more viruses. *Experimental and Applied Acarology* 30: 29–105.

Ciampolini M, Rota P (1972) Presenza in Italia di *Panonychus citri* (McGregor) (Acarina, Tetranychidae). *Bollettino di Zoologia Agraria e di Bachicoltura* 11: 195–205.

Ciglar I, *Barić* B (1998) Pernicious insects and mites fauna in Croatian orhards. *Entomologia Croatica* 4: 63–69.

Cole JS, Sabol-Jones M, Karolewski B, Byford T (2005) *Ornithonyssus bacoti* infestation and elimination from a mouse colony. *Contemporary Topics in Laboratory Animal Science* 44: 27–30.

Colin ME (1982) "La Varroatose." *Le Point Vétérinaire* 14: 21–28.

Croft BA, Pratt PD, Koskela G, Kaufman D (1998) Predation, reproduction, and impact of phytoseiid mites (Acari: Phytoseiidae) on cyclamen mite (Acari: Tarsonemidae) on strawberry. *Journal of Economic Entomology* 91: 1307–1314.

Dautel H, Kahl O (1999) Ticks (Acari: Ixodoidea) and their medical importance in the urban environment. In: Robinson WH, Rettich F, Rambo GW (Eds) *Proceedings of the Third International Conference on Urban Pests*,19–22 July 1999, Prague, Czech Republic, 73–82.

De Rycke PH, Joubert JJ, Hossein Hosseinian S, Jacobs FJ (2002) "The possible role of Varroa destructor in the spreading of American foulbrood among apiaries." *Experimental and Applied Acarology* 27: 313–318.

Delrio G, Ortu S, Prota R (1979) Aspects of integrated control in the citrus cultures of Sardinia. *Studi Sassaresi* 27: 205–232.

Denmark HA (1968) (revised 2006) Phalaenopsis mite, *Tenuipalpis pacificus* Baker (Acarina: Tenuipalpidae). *Entomology Circular* 74: 1p.

Denmark HA (1978) A mite, *Brevipalpus russulus* (Boisduval 1867) in Florida (Acarina: Tenuipalpidae). *Entomology Circular* 188: 1–2.

Denmark HA, Cromroy HL (2008) Tropical Fowl Mite, *Ornithonyssus bursa* (Berlese) (Arachnida: Acari: Macronyssidae). Bulletin EENY-297. Gainesville, Florida: University of Florida. 3 pp.

Deutsche Dahlien, Fuchsien, Gladiolen und Kübelpflanzen. *Fuchsiengallmilbe*. http://www.ddfgg.de/Allgemein/aktuell/Archiv/index_Fuchsiengallmilbe_2.html.

Dobosz R, Skorupska A, Blaszak C (1995) The appearance of spider mites (Tetranychidae) in parks of Poznan. In: Boczek J, Ignatowicz S, *Materialy z Sympozjum na temat: "Osiagniecia Akarologii w Polsce"*, Komitet Ochrony Roslin Polska Akademia Nauk, Siedlce, 39–42.

Drenski P (1955) Săstav i razprostranenie na kărležite (Ixodoidea) v Bălgarija (s ogled na medicinskoto i veterinarnoto im značenie [Artbestand und Verbreitung der Zecken (Ixodoidea) in Bulgarien (im Hinblick auf ihre medizinische und tierärtztliche Bedeutung)].(in Bulgarian, Russian and German summary). *Bulletin* of the *Institute* of *Zoology* (Sofija) 4–5: 109–168.

Easterbrook MA 1996. Damage and Control of Eriophyoid Mites in Apple and Pear. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 527–541.

Easterbrook JD, Kaplan JB, Glass GE, Watson J, Klein SL (2008) A survey of rodent-borne pathogens carried by wild-caught Norway rats: a potential threat to laboratory rodent colonies. *Laboratory Animals* 42: 92–98.

Emmanouel NG, Papadoulis GT (1987) *Panonychus citri* (MacGregor) (Tetranychidae) and *Eriophyes medicaginis* K. (Eriophyidae): two important phytophagous mites recorded for the first time in Greece. *Entomologia Hellenica* 5: 3–6.

EPPO (2002) List of biological control agents widely used in the EPPO region. *EPPO Bulletin* 32: 447–461.

Eriksson NE (1990) Allergy screening with Phadiatop and CAP Phadiatop in combination with a questionnaire in adults with asthma and rhinitis. *Allergy* 45: 285–292.

Estación Fitopatolóxica do Areeiro. *Cosetacus camelliae* (*Keifer*). *Camellia flower bud drop*. http://www.efa-dip.org/en/Publicaciones/FTecnicas/Ficha9_1.htm.

Estrada-Peña A, unpublished observations.

Evans WD, Krantz G, Lindquist E (1996) *Acari. The Mites.* Version 13 December 1996. http://tolweb.org/Acari/2554/1996].12.13 in The Tree of Life Web Project, http://tolweb.org/.

Fan Y, Petit FL (1998) Dispersal of the broad mite, *Polyphagotarsonemus latus* (Acari: Tarsonemidae) on *Bemisia argentifolii* (Homoptera: Aleyrodidae). *Experimental and Applied Acarology* 22: 411–415.

Fauna Europaea. http://www.faunaeur.org.

Fauna Italia. *Eriophyidae*. http://www.faunaitalia.it/checklist/invertebrates/families/Eriophyidae.html.

Feider Z (1965) Arachnida, Volumul V, Fascicula 2. Acaromorpha, Suprafamilia Ixodoidea (Capuse). In: *Fauna Republicii Populare Romane*. Bucarest: Editura Academiei Republicii Populare Romane, Romania, 89–104.

Ferragut F, Escudero LA (1999) *Tetranychus evansi* Baker & Pritchard (Acari, Tetranychidae), una nueva araña roja en los cultivos horticolas españoles. *Boletín de Sanidad Vegetal*, *Plagas* 25: 157–164.

Ferragut F, Escudero LA, Olmeda T (1997) *Tetranychus evansi* Baker & Pritchard (Acari: Tetranychidae), una nueva araña roja en los cultivos hortícolas españoles. *Resúmenes de las VI Jornadas Científicas de la Sociedad Española de Entomología Aplicada*. Leida, Spain: Edición*s* Universitat de Lleida: 66.

Ferragut F, Santonja MC (1989) Taxonomia y distribucion de los acaros del genero *Tetranychu*s Dufour 1832 (Acari: Tetranychidae), en Espana *Boletín de Sanidad Vegetal*, *Plagas* 15: 271–281.

Ferreira MA, Carmona MM (1995) Acarofauna do tomateiro em Portugal. *Avances en Entomologia Ibérica, Museo Nacional Ciencias Naturales y Universidad de Madrid*: 385–392.

Garben AF, Bosman BT, Bronswijk JEMH v (1980) [The brown dog tick *Rhipicephalus sanguineus* Latreille 1806 in the Netherlands, an analysis of imported cases, including their veterinary and medical significance] (in Dutch). *Tijdschrift voor Diergeneeskunde* 105: 192–203.

Garcia E, Marquez AL, Orta S, Alvarado P (2003) Caracterizacion de la presencia de *Eutetranychus banksi* (McGregor) y *Eutetranychus orientalis* (Klein) en el Sur de Espana. *Phytoma - España* 153: 90–96.

Garcia Mari F, de Rivero JM (1981) El acaro rojo *Panonychus citri* (McGregor), nueva plaga de los citricos en Espana. *Boletin del Servicio de Defensa contra Plagas e Inspeccion Fitopatologica* 7: 65–77.

Garcia Mari F, Gonzalez-Zamora JE (1999) Biological control of *Tetranychus urticae* (Acari: Tetranychidae) with naturally occurring predators in strawberry plantings in Valencia, Spain. *Experimental and Applied Acarology* 23: 487–495.

Gerson U (1992) Biology and control of the broad mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae). *Experimental and Applied Acarology* 13: 163–178.

Gjelstrup P, Møller AP (1985) A tropical mite, *Ornithonyssus bursa* (Berlese, 1888) (Macronyssidae, Gamasida) in Danish Swallow (*Hirundo rustica*) nests, with a review of mites and ticks from Danish birds. *Entomologiste Meddelelser* 53: 119–125.

Glavendekić M, Mihajlović LJ, Petanović R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro In Plant protection and plant health in Europe. In: *Abstracts of the Conference Plant Protection and Plant Health in Europe, 'Introduction and spread of invasive species'*, Berlin, Germany: Humboldt University, June 2005.

González Núñez M, Budia F, Viñuela E, Esteban Durán JR, Adan A, Medina P, Schneider M, Del Estal P (2002) Primera cita en España del eriófido de la alcachofa *Aceria neocynarae* (Keifer). *Boletín de Sanidad Vegetal, Plagas* 28: 415–418.

Griffiths DA, Bowman CE (1981) "World distribution of the mite *Varroa jacobsoni*, a parasite of honeybee." *Bee World* 62: 154–163.

Guttierez J, Kreiter S, Brain F, Cotton D (1986) Les acariens, ravageurs mal connus du cypress. *Phytoma-La défense des végétaux* 376: 47–48.

Hadžistević D (1955) [Occurence of agricultural pests during twenty years (1934–1953) in Yugoslavia]. *Plant protection* (in Serbian) 27: 89–120.

Harbo JR, Harris JW (2005) Suppressed mite reproduction explained by the behavior of adult bees. *Journal of Apicultural Research* 44: 21–23.

Hance T, Neuberg P, Noel-Lastelle C (1998) The use of fecundity, lobe biometry and the RAPD-PCR technique in order to compare strains of *Tetranychus sp*. *Experimental & Applied Acarology*, 22: 649–666.

Hatzinikolis EN (1968) Liste d'acariens de la sous-famille Tetranychinae trouvés sur les plantes cultivées en Grèce. *Annales de l'Institut Phytopathologique Benaki* 8: 193–194.

Hatzinikolis EN (1970) Neuf espèces d'acariens signalées pour la première fois en Grèce. *Annales de l'Institut Phytopathologique Benaki* 9: 238–241.

Hatzinikolis EN (1986) The genus *Tetranychus* Dufour, 1832, in Greece (Acari : Tetranychidae). *Biologia Gallo-hellenica* 12: 383–388.

Helle W, Sabelis MW (eds.) 1985. *Spider mites: their biology, natural enemies and control. Vol. 1A*. Amsterdam, The Netherlands: Elsevier. 405 pp.

Hetenyi E (1954) A gyapoton é lö takacsatkak (*Tetranychus urticae* Koch) és az ellen ük valo védekezés. *Növényvédelen* (*Plant protection*) 1: 11–19.

Heungens A (1986) Soft-skinned mites in azalea culture and comparable control results on other host plants. *Verbondsnieuws voor de Belgische Sierteelt* 30: 257–269.

Hoogstraal, H. (1956) *African Ixodoidea. Ticks of the Sudan*. Cairo, Egypt: U.S. Naval Medical Research Unit., 1099 pp.

Hoogstraal H (1979) The epidemiology of tick-borne Crimean-Congo hemorrhagic fever in Asia, Europe and Africa. *Journal of Medical Entomology* 15: 307–417.

Hughes AM (1976) *The mites of stored foods and houses. Technical bulletin of the ministry of agriculture*. London: Technical Bulletin of the Ministry of Agriculture, Fisheries & Food, No. 9. 400 pp.

James DK (2005) *Biting mites in homes of Alameda county*. Alameda County Vector Control Services District. http://www.acvcsd.org/ biting_mites.pdf.

Jeppson LR, Keifer HH, Baker EW (1975) *Mites injurious to economic plants*. Berkeley, California: University of California Press. 614 pp.

Keifer HH (1975) Injurious eriophyoid mites. In Jeppson LR, Keifer HH, Baker EW (eds.) *Mites injurious to economic plants*. Berkeley, California: University of California Press, 397–533.

Krantz GW, Walter, D.E. (eds.) 2009. *A manual of Acarology, 3rd Edition*. Lubbock, Texas: Texas Tech University Press, 807 pp.

Kropczynska D (1984) The role of predaceous mites (Phytoseidae) as natural enemies of *Eotetranychus tiliarium* (Hermann) in town conditions. *Publications of Warsaw Agricultural University, SGGW-AR* (*Treatises and Monographs*): 1–68.

Labanowski GS (1999) Occurrence and chemical control of introduced ornamental glasshouse pests in Poland. OEPP/*EPPO Bulletin*, 29, 73–76.

Le Conte Y, de Vaublanc G, Crauser D, Jeanne F, Rousselle JC, Bécard JM (2007) Honey bee colonies that have survived *Varroa destructor*. *Apidologie* 38: 566–572.

Manson DCM (1967) Mites of the families Tenuipalpidae and Tetranychidae intercepted entering New Zealand from overseas. *New Zealand Journal of Science 10*: 664–674.

Margolies DC (1993) Adaptation to spatial variation in habitat: spatial effects in agroecosystems. In Ke Chung K, McPheron BA (eds.) *Evolution of insects pests: patterns of variation*. New York: John Wiley & Sons Inc., 129–144.

Margolies DC (1995) Evidence of selection on spider mite dispersal rates in relation to habitat persistence in agroecosystems. *Entomologia Experimentalis et Applicata* 76: 105–108.

Mc Coy CW (1996) Damage and control of Eriophyoid mites in crops. Stylar feeding injury and control of Eriophyoid in citrus. Evolutionary ecology: life history patterns, food plant choice and dispersal. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 513–526.

McMurtry JA, Croft BA (1997) Life-styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology* 42: 291–321.

Migeon A (2003) *Eurytetranychus admes*: un nouvel acarien tétranyque sur les cyprès en France. *Phytoma - La Défense des Végétaux*, 561: 30–31.

Migeon A (2005) Un nouvel acarien ravageur en France: *Tetranychus evansi* Baker et Pritchard. *Phytoma - La Défense des Végétaux*, 579: 38–43.

Migeon A (2007) Acarien rouge de la tomate: nouvelles observations et perspectives. *PHM Revue Horticole*, 488: 20–24.

Migeon A, Cros-Arteil S, Navajas M (2004) The use of taxonomical and ecological databases combined with the genetic approach for tracking spidermite invasions. In: Weigman G, Alberti G, Wolhtmann A, Ragusa S Acarine biodiversity in the natural and human sphere. *Phytophaga Berlin,* 14: 757–765.

Mijušković M (1953) [Quelques maladies et insectes nuisibles aux agrumes au Montenegro] (in Serbian). *Zaštita Bilja*, 19: 47–60.

Mijušković M (1973) [*The study of mites on the Citrus trees on the Yugoslav littoral - final technical report*] (in Serbian). Titograd (Podgorica), Montenegro: Agriculture Research Institute, 239.

Mijušković M, Tomašević B (1975) [*The mites on the citrus trees on the Yugoslav littoral*] (in Serbian). Titograd (Podgorica), Montenegro: Society for Sciences and Art of Montenegro. 204 pp.

Morel P-C, Battelli C, Sobrero L (1977) *Hyalomma detritum scupense* Schulze in Italia. *Atti Societá italiana di Scienze veterinari* 31: 739–740.

Morse RA, Goncalves LS (1979) Varroa disease, a threat to world beekeeping. *Gleanings in Bee Culture* 107: 179–181.

Musken H, Franz JT, Wahl R, Paap A, Cromwell O, Masuch G, Bergmann KC (2000) Sensitization to different mite species in German farmers: Clinical aspects. *Journal of Investigational Allergology and Clinical Immunology* 10: 346–351.

Natarajan K (1988) Transport of yellow mite *Polyphagotarsonemus latus* by cotton whitefly. *Current Science* 57: 1142–1143.

Neumann LG (1911) *Ixodidae. Tierreich 26*. Berlin: R. Friedlander und Sohn. 169 pp.

Oldfield GN (1996) Diversity and host plant specificity. I In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 195–216.

Ostoja-Starzewski JC (2000) *Schizotetranychus celarius* (Banks) (Acari: Prostigmata) a mite pest of bamboo; first records for Britain and two new host records. *British Journal of Entomology & Natural History* 13: 95–97.

Ostojá-Strazewski JC, Eyre D, Cannon RJ, Bartlett P (2007) *Update on Fuchsia gall mite* Aculops fuchsiae *Keifer*. Sand Hutton, York, UK: CSL, Plant pest notice. No.5I.

Ostojá-starzewski JC, Halstead AJ (2006) *Trisetacus chamaecypari* Smith (Acari: Phytoptdiae) damaging Leyland Cypress in Britain: a new host and country record for this mite. *British Journal of Entomology and Natural History* 19: 201–205.

Pande YD, Carnero A, Hernandez M (1989) Notes on biological observations on some unrecorded species of phytophagous and predatory mites in Canary. *Islands Investigación agraria, Producción y protección vegetales* 4: 275–281.

Papaioannou-Souliotis P, Tsagarakou A, Dermatas P (1993) Integrated pest control in citrus-groves, evaluation on new acaricides used in the treatment of citrus red mite (*Panonychus citri* Koch.). *Bulletin Oilb/Srop* 16: 125–131.

Parker R, Gerson U (1994) Dispersal of the broad mite, *Polyphagotarsonemus latus* (Banks) (Heterostigmata: Tarsonemidae), by the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae). *Experimental and Applied Acarology* 18: 581–585.

Pérez Otero R, Mansilla Vázquez P, Salinero Corral MC, Sainz Oses J (2003) Occurrence of Mites in CamelliaTrees Grown in Parks and gardens in Northwest Spain. *American Camellia Yearbook* 45–50.

Petanović R (1980) Some morphological characteristics of importance in the differentiation of *Panonychus ulmi* Koch. and *Panonychus citri* McGregor (Tetranychidae, Acarina). *Interim report Arhiv Za Poljoprivredne Nauke* 41: 517–522.

Petanović R (1988) *Eriofidne grinje u Jugoslaviji* (*Monografija*). Beograd: Naučna knjiga. 159 pp.

Petanović R (1993) Pregled vrsta eriofida (*Acari: Eriophyoidea*) šumskih i ukrasnih biljaka na prostorima južnoslovenskih zemalja. XXI skup entomologa Jugoslavije. Beograd, 17–18.11.1993. Zbornik rezimea, str. 22.

Petanović R (1997) Allochthonous mite species (Acari) in the fauna of Yugoslavia. *Zastita Bilja* 48: 211–224.

Petanović R (1998) New data to the knowledge on the eriophyoid fauna (Acari: Eriophyoidea) in Yugoslavia. *Acta Entomologica Serbica* 3: 149–157.

Petanović R (1999) Three New Species of Eriophyid Mites (Acari: Eriophyoidea) from Serbia with the Notes on New Taxa for the Fauna of Yugoslavia. *Acta Entomologica Serbica* 4: 127–137.

Petanović R (2004) [*Atlas - Mite pests of decorative plants*] (in Serbian). Beograd: Beografik. 99 pp.

Petanović R (in prep.) *Database of Eriophyoid mite fauna of Serbia*. Still not available on the internet.

Petanović R, Boček J, Jovanović S, Stojnić B (1996) [*Eriophyoidea* (*Acari: Prostigmata*) *Fauna Durmitora, 5*] (in Serbian). CANU, Posebna izdanja, knjiga 32, Odjeljenje prirodnih nauka, knjiga 18, Podgorica.

Petanović R, Dobrivojević K (1987) Kompleks galikolnih eriofida lista šljive. *Zaštita bilja* 38: 145–156.

Petanović R, Dobrivojević K, Boczek J, Lazić S (1983) Eriofidne grinje (*Eriophyoidea: Acarina*) na korovskim biljkama u okolini Beograda. *Arhiv za poljoprivredne nauke* 44, 156 (1983/4): 455–460.

Petanović R, Mihajlović LJ, Mihajlović N, Magud B (1997) *Reckella celtis* Bog. and *Aceria bezzi* (Corti) (Acari: Eriophyoidea). Two new Species in the Balkan Fauna. *Acta Entomologica Serbica* 2: 95–106.

Petanović, R. i S. Stanković (1999) Catalogue of the Eriophyoidea (Acari: Prostigmata) of Serbia and Montenegro. *Acta Entomologica Serbica*, special issue: 1–143.

Piotrowski F (1990) *Zarys entomologii parazytologicznej*. Warszawa: PWN 5. 301 pp.

Raemaekers RHE (2001) *Agriculture en Afrique Tropicale.* Bruxelles: Direction Générale de la Coopération Internationale. 1634 pp.

Ragusa S (2002) As time goes by: a profile of Italian acarology. In Bernini F, Nannelli R, Nazzaci G, De Lillo E (eds) *Acari Phylogeny and Evolution. Adaptations in mites and ticks.* Dordrecht, The Netherlands: Kluwer Academic Publishers, 1–20.

Rambier A (1958) Les acariens nuisibles en cultures fruitières. *Comptes-Rendus des Journées Fruitières et Maraichères, Avignon*: 59–64.

Rambier AM (1982) Un acarien, sur vigne en Champagne, nouveau en France: *Tetranychus mcdanieli* McGregor 1931 du groupe *pacificus. Le Progrès Agricole et Viticole* 99: 261–263

Razowski J (1997) (Ed) *Wykaz zwierząt Polski IV. [Checklist of animals of Poland]* (in Polish). Kraków, Poland: Wydawnictwa Instytutu Systematyki i Ewolucji Zwierząt. 303 pp.

Rigamonti IE, Lozzia GC (1999) Injurious and beneficial mites on urban trees in Northern Italy. *Acta Horticulturae* 496: 177–182.

Ripka G (2007) Checklist of the eriophyoid mite fauna of Hungary (Acari:.Prostigmata: Eriophyoidea). *Acta Phytopathologica et Entomologica Hungarica* 42:59–142.

Ripka G, De Lillo E (1997) New data to the knowledgeon the eriophyoid fauna in Hungary (Acari: Eriophyoidea). *Folia Entomologica Hungarica* 58, 147–157.

Robbins RG, Karesh CPP, Leontyeva OA, Pereshkolnik SL, Rosenberg S (1998) First records of *Hyalomma aegyptium* (Acari: Ixodida; Ixodidae) from the Russian spur-thighed tortoise, *Testuda graeca nikolskii*, with an analysis of tick population dynamics. *Journal of Parasitology* 84: 1303–1305.

Rosicky B, Cerny V, Luli M (1960) Contribution à l'étude sur la présence, la distribution et al bionomie des tiques (Ixodoidea) en Albanie. *Ceskoslov Parasit* 7: 159–188.

Rota P, Biraghi C (1987) *Oligonychus ilicis* (Mc Gregor): a tetranychid mite new to Europe, phytophagous on azaleas, camellias and rhododendrons. *L'Informatore Agrario* 43: 105–107

Ruttner F (1983) *Varroatosis in honeybees: Extent of infestation and effects*. Meeting of the EC Experts' Group, The Netherlands, Wageningen.

Ruttner F, Marx G (1984) "Beobachtungen über eine mögliche Anpassung von *Varroa jacobsoni* an *Apis mellifera* L. in Uruguay." *Apidologie* 15: 43–62.

Sabelis MW, Bruin J (1996) Evolutionary ecology: life history patterns, food plant choice and dispersal. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 329–365.

Schulze P (1927) Beitrage zur Kentniss der Zecken Europas. *Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin* 1: 109–126.

Schulze P, Schlottke E (1929) Bestimmungstabellen fuer das Zeckengenus *Hyalomma* Koch s. str. *Sitzungsberichte und Abhandlungen der Naturforschenden Gesellschaft zu* Rostock 3: 32–46.

Šefrová H, Laštůvka Z (2005) *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Sengonca C, Zegula T, Blaeser P (2004) The suitability of twelve different predatory mite species for the biological control of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 111: 388–399.

Shetchenko VG, Rupais AA (1964) Four Leggd Mites (Acarina:Eriophyidae)- pests of parks in Latvia. *Fauna Latviskoi SSR,IV, Riga*: 203–239.

Sibomana G, Geerts S, De Vries T (1986) L'établissement de *Rhipicephalus sanguineus* (Latreille, 1806) à l'intérieur des maisons en Belgique. *Annales de la Société belge de médecine tropicale* 66 : 79–81.

Siroky P, Petrzelkova KJ, Kamler M, Mihalca A, Modry D (2007) *Hyalomma aegyptium* as dominant tick in tortoises of the genus *Testudo* in Balkan countries, with notes on its host preferences. *Experimental and applied Acarology* 40: 279–290.

Smith TG (1996) The genus *Hepatozoon* (Apicomplexa: Adeleina). *Journal of Parasitology* 82: 565–585.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP, Ostojá-Starzewski JC, Collins DW (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology.* 9, 307–326.

Soika G, Labanowski GS (1998) Nowe gayunki szpecieli (Eriophyoidea) w szkolkach roslin ozdobnych. *Progress in Plant Protection* 38: 416–418.

Soika G, Labanowski GS (1999) Szpeciele-sprawcy wyrosli I zneiksztalcen na roslinach ozdobnych. *Progress in Plant Protection* 39: 537–540.

Solignac M, Cornuet J, Vautrin D, Le Conte Y, Anderson D, Evans J, Cros-Arteil S, Navajas M (2005) The invasive Russian and Japanese types of *Varroa destructor*, ectoparasite mite of the Western honey bee (*Apis mellifera*), are two partially isolated clones. *Proceedings of the Royal Society of London B,* 272: 411–419.

Thind BB, Clarke P (2001) The occurrence of mites in cereal-based foods destined for human consumption and possible consequences of infestation. *Experimental and Applied Acarology* 25: 203–215.

Trotter A (1903) Galle della Penisola Balcanica e Asia Minore. *Nuovo Giornale botanico Italiano N.S.X.* 5–54: 210–233.

Vacante V (1983) Prima raccolta di Acari Tetranichidi in Sicilia. *Phytophaga* 1: 41–114.

Van Houten YM, van Stratum P (1993) Biological control of western flower thrips in greenhouse sweet peppers using nondiapausing predatory mites. *Experimental and Applied Acarology* 4: 229–234.

Van Houten YM, van Stratum P (1995) Control of western flower thrips on sweet pepper inwinterwith *Amblyseius cucumeris* (Oudemans) and *A. degenerans* Berlese. *NATO ASI series A, Life Sciences* 276: 245–248.

Vappula NA (1965) Pest of cultivated plants in Finland. *Acta Entomologica Fennica* 19: 1–239.

Vierbergen G (1989) *Panonychus citri* - na vele malen geïmporteed, tenslotte geïntroduceerd. *Verslagen en Medelingen Plantenziektenkundige Dients Wageningen* 167: 52–53.

Vierbergen G (1990) The spider mites of the Netherlands and their economic significance (Acarina: Tetranychidae). *Proceedings of the Section Experimental & Applied Entomology of the Netherlands Entomological Society* 1: 158–164.

Vierbergen G (1994) Entomology. *Panonychus citri*: a pest in the subtropics, found in the Netherlands in the open. Wageningen: Medelingen, Plant Protection Service, Diagnostic Centre, Annual Report 173: 28–30.

Wharton GW, Hansell FC (1957) Studies on the feeding habits of three species of Laelaptid mites. *Journal of Parasitology* 43: 45–50.

Whitaker JOJ, Walters BL, Castor LK, Ritzi CM, Wilson N (2007) Host and distribution lists of mites (acari), parasitic and phoretic, in the hair or on the skin of North American wild mammals North of Mexico: Records since 1974. *Faculty Publications from the Harold W. Manter Laboratory of Parasitology,* 1–173.

Witters J, Casteels H, de Bondt G (2003) Diagnostic acarological research at the Department of Crop Protection in 2002–2003. *Parasitica* 59, 107–111.

Table 7.4.1. List and characteristics of the mite species alien to Europe. Status: A: Alien to Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Diptilomiopidae								
Rhinophytoptus bagdasariani Shev. et Pog.,1985	A	Phytophagous	Asia South West	2002, RS	RS	I2, X11	*Ulmus, Quercus macranthera, Salix caprea*	Petanović (2004)
Rhyncaphytoptus negundivagrans Farkas,1966	C	Phytophagous	North America?	1960, HU	HU, RS	I2, X11	*Acer negundo*	Petanović (in prep.), Ripka (2007)
Epidermoptidae								
Epidermoptes bilobatus Rivolta, 1876	A	parasitic/predator	Asia- Tropical	1948, CZ	CZ	I, J	*Gallus*	Šefrová and Laštůvka (2005)
Eriophyidae								
Acaphylla theae (Watt & Mann, 1903)	A	Phytophagous	Asia	1983, IT	IT, ES	I2	*Camellia*	Fauna Europaea (2009), Pérez Otero et al. (2003)
Acaricalus hederae Keifer,1939	A	Phytophagous	North America	1997, RS	RS	I2, X11	*Hedera helix*	Petanović and Stanković (1999)
Aceria ambrosiae Wilson, 1959	A	Phytophagous	North America	1999, RS	RS	J(J1–J4)	*Ambrosia psilostachya, Ambrosia artemisifolia*	Petanović (1999)
Aceria byersi Keifer,1961	A	Phytophagous	North America	1981, RS	RS	X24, X25	*Cucumis sativus*	Petanović (1988), Petanović (1997)
Aceria caliberberis Keifer, 1952	A	Phytophagous	Asia South West	1998, RS	RS	I2, X11	*Berberis californica, Mahonia dyctiota*	Petanović (1998)
Aceria erinea (Nalepa, 1891)	A	Phytophagous	Asia South West	1903, BG	BE, BG, CZ, GB, LU, ME, RO, RS	I1, I2, X11, X13	*Juglans regia*	Petanović (1988)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aceria ligustri (Keifer,1943)	A	Phytophagous	North America	1995, RS	BE, HU, PL, RS	I2,FB, X11	*Ligustrum ovalifolium* , *Ligustrum* sp.	Petanović (1997), Petanović (1998), Soika and Labanowski (1998), Witters et al. (2003)
Aceria neocynarae (Keifer,1939)	A	Phytophagous	North America	1998, ES	GR, IT-SIC, PT, ES	I	*Cynara scolimus*	Fauna Europaea (2009), González Núñez et al. (2002)
Aceria paradianthi (Keifer,1952)	A	Phytophagous	North America	1987, GR	IT, PL, GR	J100	Dianthus sp.	Anagnou-Veroniki et al. (2008), Fauna Europaea (2009)
Aceria petanovicae Nalepa, 1925	A	Phytophagous	Medi-terranean East	1939, IT	FI, GB, HU, IT, RS	I2, X11	Syringa	Fauna Europaea (2009), Fauna Italia, Petanović and Stanković (1999), Ripka (2007)
Aceria sawatchense Keifer, 1965	A	Phytophagous	North America	1981, RS	RS	J (J1–J4)	Polygonum douglasii ssp. johnstoni, Polygonum lapatifolium	Petanović et al. (1983)
Aceria sheldoni (Ewing, 1937)	A	Phytophagous	Asia ?	17th, IT	ES, GR, IT, IT-SAR, IT-SIC, ME, PT	I, X13	*Citrus*	Mijušković and Tomašević (1975)
Aceria tristriata (Nalepa, 1890)	A	Phytophagous	Asia South West	1903, RS	BG, CZ, GB, LU, ME, RS	X13	*Juglans*	Petanović (1996), Trotter (1903)
Aculops allotrichus (Nalepa, 1894)	A	Phytophagous	North America	1912, RO	BG, CZ, RO			
Aculops fuchsiae Keifer,1972	A	Phytophagous	South America	2003, FR	DE, FR, GB	I1,I2	*Fuschia*	Deutsche Dahlien, Fuchsien, Gladiolen und Kübelpflanzen, Ostojá-Strazewski (2007)
Aculops gleditsiae (Keifer, 1959).	A	Phytophagous	North America	1993 RS	HU, IT, RS	X11	*Gleditsia triacanthos*	Fauna Italia, Petanović (1993), Petanović (1997), Ripka (2007), Ripka and De Lillo (1997)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aculops pelekassi (Keifer, 1959)	A	Phytophagous	Asia	1958, GR	ES, GR, IT, IT-SAR, IT-SIC, ME, MT	I, X13	*Citrus*	Mijušković and Tomašević (1975)
Aculops rhodensis (Keifer,1957)	A	Phytophagous	North America	1997, HU	HU, IT	X11, X13	*Salix alba, Salix elegnos*	Fauna Italia
Aculus ligustri Keifer, 1938	A	Phytophagous	North America	1993, IT	HU, IT, RS	X11, X13	*Ligustrum ovalifolium* , *Ligustrum* sp.	Fauna Italia, Petanović and Stanković (1999), Ripka (2007)
Anthocoptes punctidorsa Keifer, 1943	A	Phytophagous	North America	1991, IT	IT	I2, FB	*Ulmus laevis, U. pumila*	Rigamonti and Lozzia (1999)
Anthocoptes transitionalis Hodgkiss,1913	A	Phytophagous	North America	1989, RS	RS	X13	*Acer rubrum, A. monspessu-lanum*	Glavendekić et al. (2005), Petanović (1997)
Calacarus carinatus (Green, 1890)	A	Phytophagous	Asia	1983, IT	ES, HU, IT, PL	I2	*Camellia, Capsicum, Viburnum*	Fauna Europaea (2009)
Cecidophyes malifoliae Parrot, 1906	A	Phytophagous	North America	1991, RS	RS	X13	*Malus* x *domestica, Aremonia agrimonoides*	Petanović and Stanković (1999)
Cecidophyopsis hendersoni (Keifer,1954)	A	Phytophagous	North America	1991, RS	RS, PL	J100, J1	*Yucca glauca, Yucca gloriosa*	Glavendekić et al. (2005), Labanowski (1999), Petanović (2004)
Coptophylla lamimani (Keifer, 1939)	A	Phytophagous	North America	1981, RS	IT, RS, ME	I2, FB, X13	*Corylus avellana, Corylus colurna*	Petanović (1988), Rigamonti and Lozzia (1999)
Cosetacus camelliae Keifer,1945	A	Phytophagous	North America	1990, ME	ES, ME	I2, J100	*Camelia japonica*	Estación Fitopatolóxica do Areeiro (1998), Petanović (1997), Petanović and Stanković (1999)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Epitrimerus cupressi Keifer,1939	C	Phytophagous	California?	1986, ME	FR, ME	I2	*Cupressus sempervirens*	Guttierez et al. (1986), Petanović (1993)
Eriophyes emarginatae Keifer,1939	A	Phytophagous	North America	1978, RS	RS	I, X13,G1	*Prunus emarginata, P. americana, P.domestica*	Petanović (1997), Petanović and Dobrivojević (1987)
Eriophyes pyri (Pagenstecher, 1857)	C	Phytophagous	Cryptogenic	1903, ME	AT, BA, BE, BG, CH, CY, CZ, DE, DK, ES, FI, FR, GB, GR, GR-CRE, HR, HU, IE, LT, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, YU	I	Pear, apple, plum	Bebić (1955), Fauna Europaea (2009), Hadžistević (1955), Trotter (1903)
Paraphytoptus chrysanthemi Keifer,1940	A	Phytophagous	North America	1997, RS	RS	X25,J100	*Chrysan-themum morifolium*	Petanović (1997), Petanović and Stanković (1999)
Phyllocoptes amaranthi (Corti, 1917)	A	Phytophagous	South America	1981, RS	RS	J (J1–J4)	*Amaranthus muricatus, A. retroflexus*	Petanović et al. (1983)
Phyllocoptes azaleae Nalepa, 1904	A	Phytophagous	Asia- East	1952, CZ	BG, CZ, DE, IT, NL	G	*Rhododendron*	Fauna Europaea (2009), Šefrová and Laštůvka (2005)
Reckella celtis Bagdasarian,1975	A	Phytophagous	Armenia	1995, RS	MK, RS	G1, X13	*Celtis caucasiaca, Celtis australis*	Petanović et al. (1997)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Shevtchenkella brevisetosa (Hodgkiss,1913)	A	Phytophagous	North America	1999, RS	HU, PL, RS	X11, X24	*Acer negundo. A. negundo* var. *californicum, A.campestre*	Petanović (in prep.)
Shevtchenkella erigerivagrans (Davis, 1964)	A	Phytophagous	North America	1989, RS	RS	J (J1–J4)	*Erigeron strigosus , Taraxacum officinale, Artemisia absinthium*	Petanović and Stanković (1999)
Tegolophus califraxini (Keifer, 1938)	A	Phytophagous	North America	1988, IT	HU, IT	I2, X10–X13, X20	*Fraxinus angustifolia*	Fauna Italia, Ripka (2007), Ripka and De Lillo (1997)
Vasates quadripedes Shimer 1869	A	Phytophagous	North America	1957, LV	HU, LV, RS, PL	I2,FB	*Acer saccharinum, A.pseudo-platanus, A. rubrum*	Petanović and Stanković (1999), Ripka (2007), Shetchenko and Rupais (1964), Soika and Labanowski (1999)
Ixodidae								
Amblyomma latum Koch, 1844	A	parasitic/predator	Africa	2004, ES	ES	E	Reptile, python	Brotóns and Estrada-Peña (2004)
Amblyomma exornatum Koch, 1844	A	Parasitic/predator	Africa	2004, ES	ES	E	Reptile, phyton	Estrada-Peña (Unpubl.)
Dermacentor variabilis (Say, 1821)	A	parasitic/predator	North America	?, DK	DK	G	Dog (transmit Lyme disease)	
Hyalomma aegyptium (L., 1758)	A	parasitic/predator	Africa	1911, DE	AL, BE, BG, CY, DE, ES, FR, GB, GR, GR-CRE, IT, PT, RO, RU	I	Tortoises (transmit *Borellia*)	Brotóns and Estrada-Peña (2004), Feider (1965), Neumann (1911), Robbins et al. (1998), Schulze (1927), Siroky Pet al. (2007)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Hyalomma anatolicum Koch 1844	A	parasitic/predator	Cryptogenic	1929, CY	CY	F4, F5, F6, F7	Cattle	Apanaskevich (2003), Schulze and Schlottke (1929)
Hyalomma dromedarii Koch 1844	A	parasitic/predator	Africa	1929	BG, ES-CAN	F4, F5, F6, F7	Camels	Drenski (1955), Schulze and Schlottke (1929)
Hyalomma excavatum Pomerantsev 1946	A	parasitic/predator	Cryptogenic	1940	AL, BG, CY, ES-CAN, GR, GR-CRE, IT	F4, F5, F6, F7	Cattle	Apanaskevich (2003), Battelli et al. (1977), Drenski (1955), Rosicky et al. (1960)
Hyalomma truncatum Koch 1844	A	parasitic/predator	Cryptogenic	1956 ES-CAN	ES-CAN	F4, F5, F6, F7	Cattle	Hoogstraal (1956)
Rhipicephalus rossicus Yakimov & Kolyakimova, 1911	A	parasitic/predator	Cryptogenic	1965, RO	RO	F4, F5, F6, F7	Domestic animals, hedgehogs, occasionally humans (transmit Crimean congo haemorragic fever)	Feider (1965)
Laelapidae								
Laelaps echidninus Berlese, 1887	A	parasitic/predator	Asia- Tropical	1955, CZ	CZ	G	spiny rat	Šefrová and Laštůvka (2005), Smith et al. (2007), Wharton and Hansell (1957)
Ondatralaelaps multispinosus (Banks, 1909)	A	parasitic/predator	North America	1955, CZ	CZ	C	Muskrat	Šefrová and Laštůvka (2005)
Listrophoridae								
Listrophorus americanus Radford, 1944	A	parasitic/predator	North America	1955, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005), Whitaker (2007)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Listrophorus dozieri Redford, 1994	A	parasitic/predator	North America	2004, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Listrophorus faini Dubinina, 1972	A	parasitic/predator	North America	2004, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Listrophorus validus Banks, 1910	A	parasitic/predator	North America	2004, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Macronyssidae								
Ornithonyssus bacoti (Hirst, 1913)	A	parasitic/predator	Asia- Tropical	1952, CZ	CZ	G, I, J	tropical rat, rat, mices, little rodents	Bowman et al. (2003), Cole et al. (2005), Easterbrook et al. (2008), James (2005), Šefrová and Laštůvka (2005), Whitaker (2007)
Ornithonyssus bursa (Berlese)	A	parasitic/predator	C & S America	1948, CZ	CZ, DK	G, I, J	birds, mammals	Berggren (2005), Denmark and Cromroy (2008), Gjelstrup and Møller (1985), James (2005)
Myocopidae								
Myocoptes ondatrae Lukoschus & Rouwet, 1968	A	parasitic/predator	North America	2004, CZ	CZ	C, 1	Muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Phytoptidae								
Phytoptus hedericola Keifer, 1943	A	Phytophagous	South Africa	2002, RS	RS	I2, X11	*Hedera helix*	Glavendekić et al. (2005)
Setoptus strobicus Keifer,1966	A	s	North America	2005, RS	RS	G3F, X25, X11	*Pinus strobus*	Petanović (in prep.)
Sierraphytoptus alnivagrans Keifer, 1939	A	Phytophagous	North America	2007, RS	RS	G1	*Alnus glutinosa*	Petanović (in prep.)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Trisetacus chamaecypari Smith, 1977	A	Phytophagous	North America	2002	GB	I2	*Chamecyparis, lawsonianna, C. nootkaensis, Cupressus macrocarpa, Juniperus virginiana*	Ostojá-starzewski and Halstead (2006), Smith et al. (2007)
Phytoseiidae								
Phytoseiulus persimilis Athias-Henriot 1957	A	parasitic/predator	South America	1974,CZ	BG, CZ, BE, DE, ES, GB, IT	I	Predator of *Tetranychus*	Bartlett (1992), Croft et al. (1998), Easterbrook (1996), EPPO (2002), Garcia Mari and Gonzalez-Zamora (1999), Helle and Sabelis (1985), McMurtry and Croft (1997), Šefrová and Laštůvka (2005)
Amblyseius (Neoseiulus) californicus (McGregor 1954)	A	parasitic/predator	North America	1991, GB	BG, CZ, GB, IT	I	Predator of *Tetranychus*	Croft et al. (1998), Easterbrook (1996), EPPO (2002), Garcia Mari and Gonzalez-Zamora (1999), Helle and Sabelis (1985), McMurtry and Croft (1997), Šefrová and Laštůvka (2005)
Typhloctonus squamiger Wainstein 1960	A	Phytophagous	Cryptogenic	1991, IT	IT	I	*Acer platanoides, Prunus serratulata*	Rigamonti and Lozzia (1999)
Pyroglyphidae								
Dermatophagoides evansi Fain, Hughes et Johnston, 1967	A	parasitic/predator	North America	Unknown	NL, NO, PL, IT	J	house dust	Bigliocchi and Maroli (1995), Eriksson (1990), Hughes (1976), Musken et al. (2000), Piotrowski (1990), Razowski (1997), Thind and Clarke (2001)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tarsonemidae								
Polyphagotarsonemus latus (Banks, 1904	A	Phytophagous	Sri Lanka	IT, 1965	DK, ES, GB, IT, IT-SAR, IT-SIC, NL, RO, RS, BE, DE	I	polyphagous: crops, vegetables, fruits and leaves	CAB-International (1986), Fan and Petit (1998), Gerson (1992), Heungens (1986), Natarajan (1988), Parker and Gerson (1994), Raemaekers (2001)
Tenuipalpidae								
Brevipalpus californicus (Banks, 1904)	A	Phytophagous	North America	IT, 1998	CY, FR, GR-CRE, GR, IT, IT-SAR, IT-SIC, PT, IL	I2, J100	*Citrus, Camellia sinensis*	CAB-International (1986), Childers et al. (2003a), Childers et al. (2003b)
Brevipalpus lewisi (McGregor 1949)	A	Phytophagous	North America	Unknown	BG, FR, GR, RO	I2, J100	*Citrus*, ornamentals	Childers et al. (2003a)
Brevipalpus phoenicis (Geijskes 1939)	A	Phytophagous	Tropical	IT, 1998	ES, GR, IT, NL	I2, J100	Polyphagous, *Citrus, Gardenia, Hibiscus, Ilex, Ligustrum; Ficus, Phoenix, Prunus*	Childers et al. (2003a), Childers et al. (2003b)
Brevipalpus obovatus Donnadieu, 1875	A	Phytophagous	North America	IT, 1986	AT, FR, DE, IL, NL, SP, RS, BE, BA, BG, HR, CY, GR, IT, PT, RO, UA	I2	*Citrus, Camellia, Coffea, Mentha, Solanum*	CAB-International (1986), Childers et al. (2003a), Childers et al. (2003b), Glavendekić et al. (2005), Manson (1967)
Brevipalpus russulus (Boisduval 1867)	A	Phytophagous	C & S America	1867, FR	BE, DE, FR, GB, GR, NL, PT, UA	J100	Cactaceae	Denmark (1978)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Tenuipalpus caudatus (Dugès 1834)	A	Phytophagous	Tropical	Unknown	FR, GR, IT, PT	I2, J100	*Citrus*	Manson (1967)
Tenuipalpus pacificus Baker 1945	A	Phytophagous	C & S America	Unknown	DE, GB, NL, RO, RS	J100	Orchids: *Phalaenopsis*, etc..	Denmark (1968), Glavendekić et al. (2005), Manson (1967)
Tetranychidae								
Eotetranychus lewisi (McGregor, 1943)	A	Phytophagous	C & S America	1990, PT-MAD	PT-MAD	I	*Citrus, Carica*	Carmona (1992)
Eotetranychus weldoni (Ewing, 1913)	A	Phytophagous	North America	2004, RS	AL, MK, RS	I	*Populus*	Glavendekić et al. (2005)
Eurytetranychus admes Pritchard & Baker, 1955	A	Phytophagous	North America	1970, HU	FR, HU	I2	Coniferous	Bozai (1970), Migeon (2003)
Eurytetranychus furcisetus Wainstein, 1956	A	Phytophagous	Asia-Temperate	1974, HU	HU	G	*Picea*	Bozai (1974)
Eutetranychus banksi (McGregor, 1914)	A	Phytophagous	C & S America	2001, ES	ES, PT	I	*Citrus*	Garcia et al. (2003)
Eutetranychus orientalis (Klein, 1936)	A	Phytophagous	Asia-Tropical	2001, ES	ES	I	*Citrus*	Garcia et al. (2003)
Oligonychus bicolor (Banks, 1894)	A	Phytophagous	North America?	1972, IT	IT-SAR, IT-SIC, IT, PT	I2	*Quercus robur, Castanea*	Rigamonti and Lozzia (1999)
Oligonychus ilicis (McGregor, 1917)	A	Phytophagous	Asia-Temperate	1985, IT	IT, NL	I2	*Azalea, Rhododendron, Camelia*	Rota and Biraghi (1987)
Oligonychus laricis Reeves, 1963	A	Phytophagous	North America	1964, PL	PL	I2	*Larix*	Boczek (1964), Doboz et al. (1995)
Oligonychus perditus Pritchard & Baker, 1955	A	Phytophagous	Asia-Temperate	1990, NL	NL	I2	*Juniperus chinensis*	Vierbergen (1990)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Oligonychus perseae Tuttle, Baker & Abbatiello, 1976	A	Phytophagous	North America	2004, ES	ES	I1	*Persea americana*	Alcázar et al. (2005)
Oligonychus pritchardi (McGregor, 1950)	A	Phytophagous	North America	1984, PL	PL	G	*Quercus robur*	Kropczynska (1984), Doboz et al. (1995)
Oligonychus punicae (Hirst, 1926)	A	Phytophagous	C & S America	1988, FR-COR	FR-COR	I2	polyphagous: *Quercus, Juglans, Eucalyptus*	Bolland et al. (1998)
Panonychus citri (McGregor, 1916)	A	Phytophagous	Asia	1950, FR	AL, BG, ES, ES-CAN, FI, FR, GB, GR-CRE, GR, HR, HU, IT, IT-SAR, IT-SIC, MK, NL, NO, PL, PT, RO, SI, UA, YU	I1, I2	*Citrus*	Balevski (1967), Bernini et al. (1995), Bowman and Bartlett (1978), Bozai (1970), Ciampolini and Rota (1972), Ciglar and Barić (1998), Delrio et al. (1979), Emmanouel and Papadoulis (1987), Fauna Europaea (2009), Garcia Mari and de Rivero (1981), Jeppson et al. (1975), Mijušković (1953), Pande et al. (1989), Petanović (1980), Rambier (1958), Vacante (1983), Vappula (1965), Vierbergen (1989)
Petrobia (Tetranychina) lupini (McGregor, 1950)	A	Phytophagous	North America	1968, GR	GR	I	*Lupinus.*, *Fragaria*, Poaceae	Hatzinikolis (1970), Papaioannou-Souliotis et al. (1993)
Schizotetranychus bambusae Reck, 1941	A	Phytophagous	Asia-Temperate	2001, FR	FR	I2	Bambusaceae	Auger and Migeon (2007), Migeon et al. (2004)
Schizotetranychus parasemus Pritchard & Baker, 1955	A	Phytophagous	North America	1964, PL	PL	I	*Cynodon*, Poaceae	Boczek and Kropczynska (1964)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Stigmaeopsis celarius Banks, 1917	A	Phytophagous	Asia-Temperate	1985, FR	BE, FR, GB, NL	I, X11, X22, X23, X24, X25	Bambusaceae	Auger and Migeon (2007), Bolland et al. (1998), Ostoja-Starzewski (2000), Witters et al. (2003)
Tetranychus canadensis (McGregor, 1950)	A	Phytophagous	North America	1954, HU	HU, PL	I2	Polyphagous: Rosaceae, *Carya, Corylus*	Boczek and Kropczynska (1964), Hetenyi (1954)
Tetranychus evansi Baker & Pritchard, 1960	A	Phytophagous	C & S America	1991, PT	ES, ES-BAL, ES-CAN, FR, IT, PT, PT-MAD, PT	I, J100, X	Solanaceae	Castagnoli et al. (2006), Ferragut and Escudero (1999), Ferragut et al. (1997), Ferreira and Carmona (1995), Migeon (2005), Migeon (2007)
Tetranychus kanzawai Kishida, 1927	A	Phytophagous	Asia-Tropical	1966, GR	BE, GR	J100	Saxifragaceae: *Hydrangea*	Hance et al. 1998, Hatzinikolis (1968), Hatzinikolis (1986)
Tetranychus macfarlanei Baker & Pritchard, 1960	A	Phytophagous	Asia-Tropical	1989, ES-CAN	ES, ES-CAN	I	*Musa, Ipomoea*, etc	Pande et al. (1989)
Tetranychus mcdanieli McGregor, 1931	A	Phytophagous	North America	1981, FR	FR	I	*Vitis, Acer, Lonicera, Fragaria, Ulmus*, etc.	Rambier (1982)
Tetranychus neocaledonicus André, 1933	A	Phytophagous	Tropical	1989, ES-CAN	ES-CAN	I	Polyphagous: *Citrus*, Fabaceae	Ferragut and Santonja (1989)
Tetranychus sinhai Baker, 1962	A	Phytophagous	North America	1964, PL	PL	I	*Helianthus, Agropyron, Prunus*	Boczek (1964)
Tetranychus tumidellus Pritchard & Baker, 1955	A	Phytophagous	North America	1986, GR	GR	I	*Sambucus, Passiflora, Solanum*	Hatzinikolis (1986)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tetranychus yusti McGregor, 1955	A	Phytophagous	C & S America	1981, GR	GR, GR-CRE	I2, X	*Plumeria*, *Lonicera*, exotic Fabaceae	Hatzinikolis (1986)
Varroidae								
Varroa destructor Anderson & Trueman, 2000	A	parasitic/predator	Asia	1964 RS	AL, BG, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, IT-SAR, IT-SIC, MT, PL, PT, RO, RS, RU, SI, SK	J	bee parasite	Colin (1982), De Rycke et al. (2002), Griffiths and Bowman (1981), Morse and Goncalves (1979), Ruttner (1983), Ruttner and Marx (1984)

Table 7.4.2. List and characteristics of the mite species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family Species	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Argasidae							
Argas reflexus (Fabricius, 1794)	parasitic/ predator	Europe	19^{th} , DE	AT, BE, BG, CH, CZ, DE, DK, ES, FR, GB, GR, IT, PL, RO, RU, UA	J	Rat	Dautel and Kahl (1999)
Eriophyidae							
Aceria alpestris (Nalepa,1892)	Phytophagous	Alps	1952, CZ	AT, CZ, IT, RS	F2	*Rododendron ferrugineum*	Petanović and Stanković (1999)
Aceria loewi (Nalepa, 1890)	Phytophagous	Mediterranean East	1901, RO	AT, BG, CZ, CY, DE, FR, HU, IT, LT, LV, PL,GB	I2, X11	*Syringa*	Fauna Europaea (2009)
Aculus hippocastani (Fockeu, 1890)	Phytophagous	Mediterranean East	1907, CZ	BG, CZ, IT, RO, FR	G1,G4, X11	*Aesculus*	Fauna Italia
Eriophyes canestrinii (Nalepa, 1891)	Phytophagous	Mediterranean region	1998, RS	AT, BG, CZ, DE, HU, IS, PL	X 11, X24	*Buxus sempervirens*	Petanović (1998)
Glycyphagidae							
Glycyphagus domesticus (De Geer, 1778)	detrivorous	Europe	Unknown	DK, FÖ, IT, NO, PL, SE	J1, J2	Houes dust	Bigliocchi and Maroli (1995), Hughes (1976), Musken et al. (2000), Piotrowski (1990), Razowski (1997), Thind and Clarke (2001)
Ixodidae							
Hyalomma scupense Delpy 1946	parasitic/ predator	Europe	Unknown	AL, BG, ES, ES-CAN, FR, GR, HR, IT, IT-SAR, IT-SIC, MK, RU, RS, YU	J	Cattle	Morel et al. (1977)

Family Species	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Rhipicephalus sanguineus (Latreille 1806)	parasitic/ predator	Mediterranean region	Unknown	BE, CH, CZ, DE, DK, GB, IE, NL, NO, PL	J	Dogs	Černý (1985), Fauna Europaea (2009), Garben et al. (1980), Sibomana et al. (1986)
Phytoptidae							
Trisetacus laricis \(Tubeuf 1897)	Phytophagous	Alps	1912	BA,DE, GB, HR, SI	I2	*Larix*	Fauna Europaea (2009)
Phytoseiidae							
Amblyseius (Iphesius) degenerans (Berlese 1889)	parasitic/ predator	Mediterranean	1993, CZ	CZ, GB, GR, IT,PT	I	Predator of *Tetranychus*	Albajes et al. (1999), Bartlett (1992), EPPO (2002), Šefrová and Laštůvka (2005), Sengonca et al. (2004), van Houten and van Stratum (1993), van Houten and van Stratum (1995)

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Longhorn beetles (Coleoptera, Cerambycidae) Chapter 8.1

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Abstract

A total of 19 alien longhorn beetle species have established in Europe where they presently account for ca. 2.8 % of the total cerambycid fauna. Most species belong to the subfamilies Cerambycinae and Laminae which are prevalent in the native fauna as well. The alien species mainly established during the period 1975–1999, arriving predominantly from Asia. France, Spain and Italy are by far the most invaded countries. All species have been introduced accidentally. Wood-derived products such as wood- packaging material and palettes, plants for planting, and bonsais constitute invasive pathways of increasing importance. However, only few species have yet colonized natural habitats outside parks and gardens. Present ecological and economical impacts, and future trends are discussed.

Keywords

Cerambycidae, Europe, Introductions, Establishments, Biogeographical origins, Pathways, Impacts

8.1.1 Introduction

The coleopteran family Cerambycidae (longhorn beetles) is currently classified in the superfamily Chrysomeloidea, along with the families Vesperidae and Distenidae (Hunt et al. 2007, Szeoke and Hegyi 2002). Cerambycidae is a large family comprising about

40000 described species worldwide. Longhorn beetles are all phytophagous. Larvae may be found in conifer, deciduous and fruit trees, in bushes and herbaceous plants. They are mainly xylophagous borers of living, decaying or dead wood. Some species also bore small twigs, roots or fruit endocarps. They usually have a long period of larval development, some species being capable of developing in woody material a long time after the death of the tree. They are thus very susceptible to transport with wood products, facilitating their introduction and establishment.

The oldest known introduction of a longhorn beetle from one continent to another was probably that of the house borer, *Hylotrupes bajulus* (L., 1758), which was first described by Linnaeus from both Europe and 'America septentrionali' (von Linnaeus 1758). Since a study by Duffy in 1953 (Duffy 1953a) for Great Britain, there has been no further large synthesis of the alien cerambycid species introduced to Europe. Since 1999, the development of research interests in the Asian longhorn beetles, *Anoplophora* spp., in North America has raised awareness of the risks presented by cerambycid importation and provided a baseline for subsequent studies (Haack et al. 2000, Haack et al. 2010). There is an urgent need for a comprehensive literature review of the alien cerambycids that have successfully established in Europe.

The exponential growth in the volume of international trade in both horticulture and forestry has allowed an increasing number of wood products and ornamental plants potentially containing cerambycids to arrive in Europe. More than 250 species have been introduced to Europe or moved within Europe since the middle of the 18^{th} century (Cocquempot 2007) but most of them never established. We have identified 19 species alien *to* Europe that have established in Europe but have not yet been eradicated.

8.1.2 Taxonomy of the Cerambycid species alien *to* Europe

Taxonomy in Cerambycidae *sensu lato* is not well established (e.g., Hunt et al. 2007, Lawrence and Newton 1995, Napp 1994, Özdikmen 2008, Sýkorová 2008) but a general consensus exists about the presence in Europe of 7 subfamilies, namely Cerambycinae, Lamiinae, Lepturinae, Necydalinae, Prioninae, Spondylidinae, and Vesperinae (the latter being sometimes considered as a valid family). A total of 677 native species are known to occur in Europe (Althoff and Danilevsky 1997, Fauna Europaea), being largely dominated by 3 subfamilies (Lamiinae- 343 spp.; Cerambycinae- 158 spp.; Lepturinae- 130 spp.) which account for 93.2% of the total.

The 19 alien species established in Europe belong to only 3 of these subfamilies, Cerambycinae, Laminae and Prioninae (Table 8.1.1). The alien species are mostly represented by the subfamily Cerambycinae, followed by Lamiinae but the relative proportion of aliens compared to the total cerambycid fauna is still limited (<6%) in these two subfamilies. By contrast, the proportion of aliens is much more important in Prioninae with 2 species adding to 10 native ones (Fig. 8.1.1.). In addition, Parandrinae, a subfamily which is not represented in the native European entomofauna, is represented by *Parandra brunnea,* a North American species introduced in Germany (Nüssler 1961).

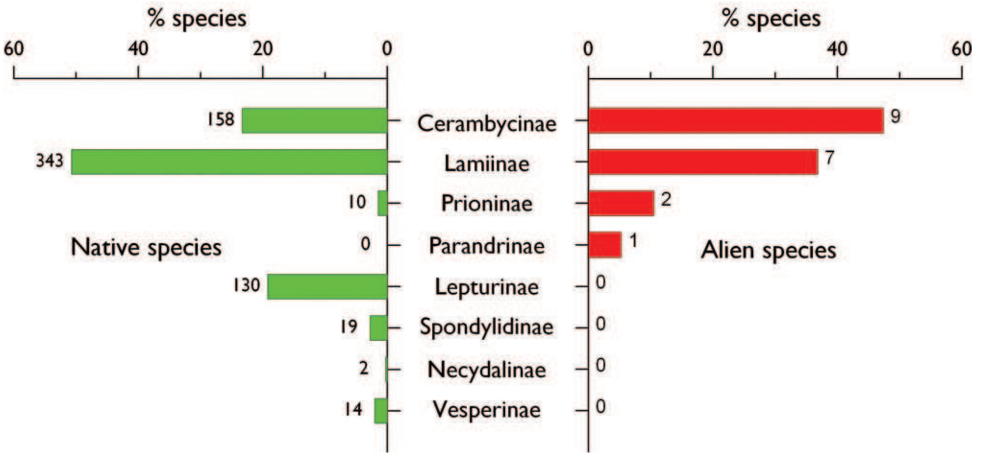

Figure 8.1.1. Relative importance of the subfamilies of Cerambycidae in the alien and native entomofauna in Europe. Subfamilies are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of species observed per family.

Two more alien species have been introduced and established in Israel, *Batocera rufomaculata* (DeGeer, 1775) (Bytinski-Salz 1956, Chikatunov et al. 1999, Sama et al. 2010) and *Xystrocera globosa* (Olivier, 1795) (Chikatunov et al. 2006, Sama et al. 2010), but they have not yet spread to Europe and were not considered in Table 8.1.1.

Table 8.1.2 gives a list of species of European origin introduced through human activity in another part of Europe (aliens *in* Europe). These species are mostly of Mediterranean origin introduced in more northern areas and species from Continental Europe introduced to the Atlantic islands.

8.1.3 Major biological characteristics of the cerambycid species alien *to* Europe

Lepturinae but also Prioninae and Parandrinae share some biological characteristics that reduce their probability of introduction. Larvae in these subfamilies develop in decaying wood and are rarely imported with wood products or living plants. Interceptions have shown that they are mainly introduced through accidental importation in industrial packages or in stocks of perishable vegetables. Only a few species of Lepturinae (Tribe Rhagiini, and some Lepturinii) developing on recently felled trees are likely to be successfully introduced through the wood trade. The importation of living potted plants is also a potential new pathway for Prioninae.

Cerambycinae and Lamiinae seem more predisposed to introduction. Most species develope in living plants and several Cerambycinae undertake their entire life-cycle in dead wood, e.g. the cosmopolitan tribe Hesperophanini and the species *Hylotrupes bajulus* and *Gracilia minuta.* Thus, Cerambycinae and Lamiinae can easily survive throughout the importation process of living plants including bonsai (e.g. *Anoplophora chinensis* (Cocquempot 2007, EPPO 2006, van Rossem et al. 1981, Schmidt and Schmidt 1990)), recently felled logs and other non-aged wood products (e.g. *Anoplophora glabripennis* (Cocquempot et al. 2003, Haack et al. 2000), *Monochamus* spp. (Cocquempot 2007, Cocquempot (Unpubl.), Duffy 1953a), *Chlorophorus annularis* (Cocquempot 2007) and *Phoracantha* spp. (Cocquempot and Debreuil 2006)). Species in the genera *Hesperophanes*, *Trichoferus*, and *Stromatium* can emerge from wood products even several years after importation (Duffy 1953a).

Once a population is introduced, the capability for natural dispersal constitutes an important factor for establishment success. Although our knowledge about the dispersal behaviour of alien longhorn beetles is still rather limited and mostly concerns only a few species of recent invaders such as *Anoplophora glabripennis* (Smith et aol. 2001) and *A. chinensis* (Adachi 1990, Komazaki and Sakagami 1989), this variable is important when designing an eradication attempt (MacLeod et al. 2002).

8.1.4 Temporal trends of introduction in Europe of alien Cerambycids

Figure 8.1.2 presents the temporal changes in the records of Cerambycid species alien *to* Europe from 1492 to 2007. Cerambycids have tracked trade routes since the beginning of overseas communications. The first species to have moved are those which live in dry wood and undergo a long stage of larval development. These species have become cosmopolitan (e.g. *Hylotrupes bajulus*) or nearly so (e.g. *Stromatium* spp.). With the increased speed of international transport from 1850 to 1925, species with shorter life cycles were able to reach Europe alive and become established, e.g. *Neoclytus acuminatus* (Reineck 1919, Sama 2002, Tassi 1969). Later, only two species were introduced from North America to Europe via the US effort to supply extra furniture and increase military material after the 1st World War (i.e., *Parandra brunnea*, *Neoclytus acuminatus*). Subsequently, 50 years passed until a second wave of introduction arrived alongside with the rapid development of international exchange of goods and transportation after the 2nd World War. During the recent period, two further species have been detected in the wild - *Anoplophora chinensis* in 2000 in Italy (Colombo and Limonta 2001) and *A. glabripennis* in 2001 in Austria (Dauber and Mitter 2001).

The number of interceptions of Cerambycids is still increasing throughout Europe. However, more effective control at borders is like to have reduced establishments following interception or introductions. The importation of exotic plants also offers opportunities for introduction but also constraints the establishment of some alien species. For example, *Phoracantha* spp. could not have been introduced without the importation and mass cultivation of its host plants, *Eucalyptus* spp. in the Mediterranean basin. In south-eastern France, an Australian cerambycid, *Bardistus cibarius* (Newman, 1841) could survive only on its original host plant, an introduced grass tree (*Xanthorrhoea* sp., Xanthorrhoeaceae); the beetle population disappeared immediately after the infested host plants were removed (Cocquempot 2007). The case of *Batocera*

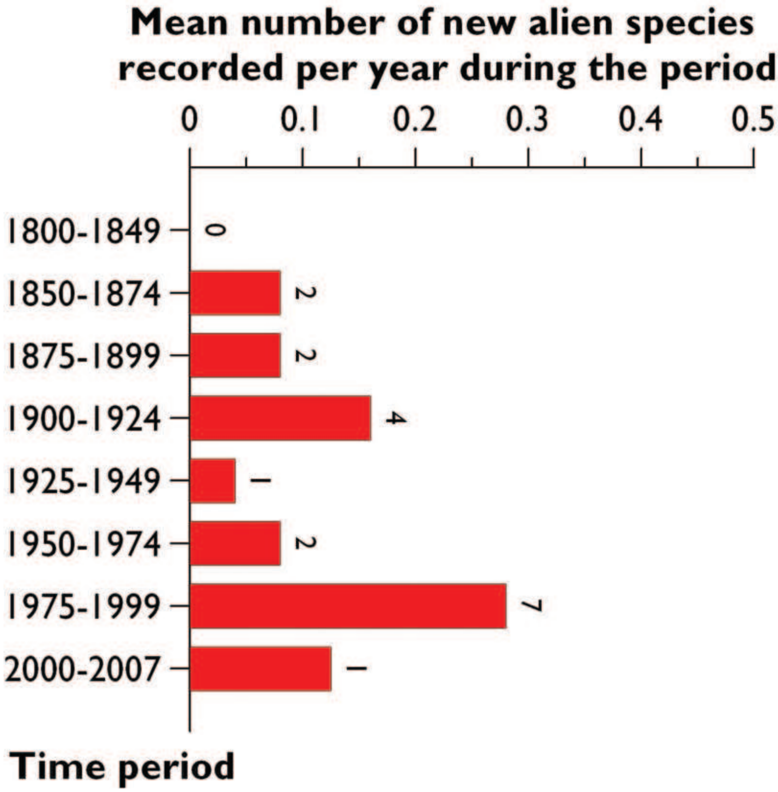

Figure 8.1.2. Temporal changes in the mean number of new records per year of Cerambycid species alien *to* Europe from 1492 to 2007. The number over each bar indicates the absolute number of species newly recorded per time period.

rufomaculata (DeGeer, 1775) found in Munster's Zoo (Germany) is similar (Cocquempot 2007) although this tropical species has established in Israel since at least 1948 (Bahillo de la Puebla and Iturrondobeitia-Bilbao 1995, Plavilstshtikov 1934, Sama et al. 2010). The combination of importation of longhorn beetle species with their specific host plant or groups of plants followed by establishment is rare. However the establishment of *A. chinensis* is an exception. Other species are frequent intercepted at border controls, e.g. *Mimectatina meridiana* (Matsushita, 1933) with *Cycas* fruits from Japan (Cocquempot 2007) or *Trichoferus campestris* (Faldermann 1835) with *Salix* timber from China (Cocquempot 2007).

The degree of polyphagy is also an important factor in the likelihood of establishment. Polyphagous species appear to have a higher potential to establish than oligophagous and monophagous species. The large number of hosts utilised by *Anoplophora* spp. (Cocquempot et al. 2003, Hérard and Roques 2009, Maspero et al. 2007a) is a main factor in the difficulty in eradicating this species for example. These difficulties appear much less important for oligophagous species such as *Callidiellum rufipenne* (Bahillo and Iturrondobeitia-Bilbao 1995, Campadelli and Sama 1988, Plavilstshtikov 1934) or Phoracanthine species. It is also the case for the North American wood borer *Saperda candida* (Fabricius, 1787), which was introduced in Germany in 2008 but apparently did not established yet (EPPO 2008, Nolte Krieger 2008). By contrast, *Monochamus* species have a regime close to polyphagy, including a large number of conifer species, and may spread throughout Europe. There is no example of establishment in Europe of a strictly monophagous exotic long-horned beetle. Species with a limited host range do not seem to be capable of going beyond the interception or introduction stage, e.g. *Bardistus cibarius* (Cocquempot 2007).

8.1.5 Biogeographic patterns of the cerambycid species alien *to* Europe

Alien species established in Europe mostly originated from Asia, followed by Africa (Figure 8.1.3). The region of origin appears to depend on the major trade routes developed by each country. Some North African species have colonized Mediterranean countries such as Spain, France, and Malta for example. Other African species have often been intercepted but only *Phryneta leprosa* has established in Malta where the climate is favourable for development (Mifsud and Dandria 2002). Long-established trade routes between Iberian countries and South American countries have resulted in some historic, isolated establishments in the Spanish and Portuguese Atlantic Islands but with a limited risk of further expansion (Lemos-Perreira 1978, Méquignon 1935). With the numerous interceptions in the U.K (Duffy 1953a) together with the colonial trade routes with African and Asiatic countries, it is surprising that only *Trinophylum cribratum* has established to date (Gilmour 1948); the incompatible climate may negate the development of tropical and subtropical species. Two species native to North America, *Parandra brunnea* and *Neoclytus acuminatus,* also colonized Europe at the beginning of the last century. The first species is well established but restricted to Dresden (Germany) (Nüssler 1961). The second is widely established in the Mediterranean area but its populations appear to be declining (Brustel et al. 2002). Beside these two species, there have been no further establishments originating from North America; the pathway of transported material is mainly in the reverse direction, from Europe to America.

Some Australian species have reached Europe but only those using *Eucalyptus* (*Phoracantha* spp.) have successfully established (Cocquempot and Sama 2004) and only in areas newly planted with these fast-growing tree species. The large differences in species composition between the floras of Australia and Europe probably accounts for the failure of Australasian longhorn beetles such as in *Bardistus cibarius* on *Xanthorrhoea* sp. (Cocquempot 2007) to establish.

Recent increases in commercial traffic from Asia (especially China) to Europe has accounted for the introduction of a number of new species of cerambycids. Striking examples are *Callidiellum rufipenne* which has recently established in Spain (Bahillo de la Puebla and Iturrondobeitia-Bilbao 1995) and Italy (Campadelli and Sama 1988), *Anoplophora glabripennis* and *A. chinensis* which can be considered as established or

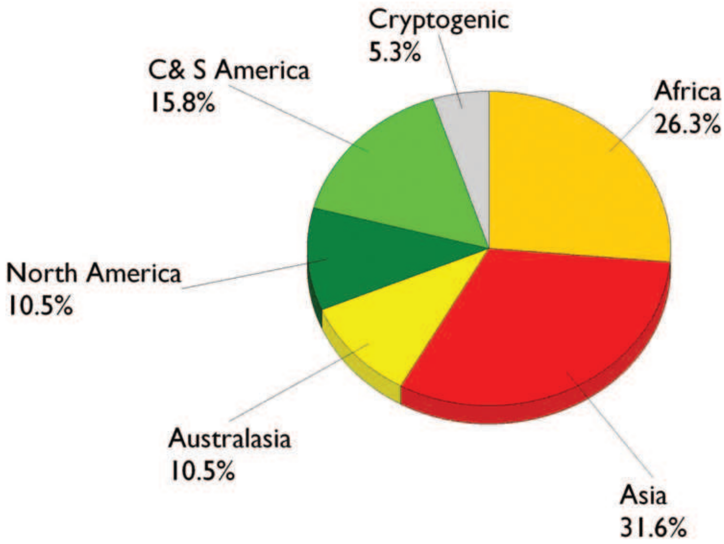

Figure 8.1.3. Origin of the Cerambycidae species alien *to* Europe

not eradicated in several countries (Hérard and Roques 2009, Maspero et al. 2007a), *Psacothea hilaris* (Pascoe, 1857) under eradication in Italy (Cocquempot 2007, Jucker et al. 2006), and *Monochamus alternatus* Hope, 1842 intercepted a number of times in Germany (Cocquempot 2007) and France (Cocquempot Unpubl.) but not yet established. A final case, *Xylotrechus stebbingi,* is less clear. It is believed that an initial introduction from its native area of central Asia to Asia Minor was followed by a step-wise expansion into southern Europe and North Africa (Cocquempot and Debreuil 2006, Sama 2002, Šefrová and Laštůvka 2005).

Alien cerambycid species are not evenly distributed throughout Europe. Large differences in the number of aliens are apparent between countries, France, Italy and Spain being by far the most invaded (Figure 8.1.4).

8.1.6 Main pathways of introduction to Europe of alien cerambycid species

All alien longhorn beetles established in Europe have been introduced accidentally; there are no examples of a successful, deliberate introduction. The principal pathways of arrival have been identified and presented by Frank 2002 and each relates to the import of immature stages that subsequently emerge as adults. There are relatively few records of living adults imported with vegetables or fruits although Eucalyptus beetles, *Phoracantha recurva,* were found in a cluster of bananas (Bosmans 2006).

The longest established pathway is timber importation for house construction (*Hylotrupes bajulus*) or building furniture (e.g. *Trichoferus* spp., *Stromatium* spp. and *Chlorophorus annularis* arriving with bamboo- made objects (Cocquempot 2007)). Species

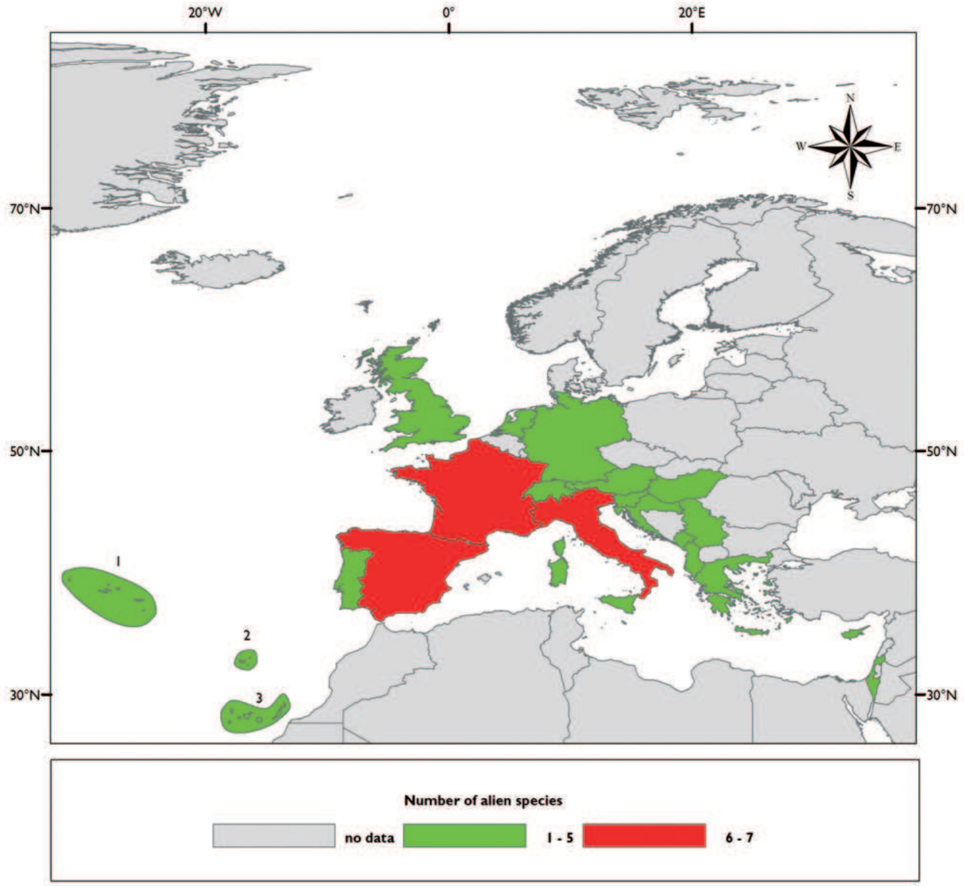

Figure 8.1.4. Comparative colonization of continental European countries and islands by Cerambycidae species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

introduced through this pathway have traditionally required a long life cycle but more rapid travel now enables the introduction of species with a one year life cycle. The second pathway is via the importation of timber for pulp (e.g., for *Phoracantha* spp.). A third, more recent, pathway concerns wood packages, palettes and other wood-derived products (e.g., for *Anoplophora glabripennis*) (Hérard and Roques 2009). The final pathway is the importation of plants for planting in nurseries, including the bonsai industry, which has resulted in the arrival of species such as *Anopolophra chinensis* (Cocquempot 2007, EPPO 2006, van Rossem et al. 1981, Schembri and Sama 1986), *Callidiellum rufipenne* and *Bardistus cibarius*.

All pathways are still prevalent but they vary in importance. Most recent interceptions (from the end of the 20th Century) have related to wood-manufactured products (e.g. *Chlorophorus annularis* and *Trichoferus campestris*). Importation of *Eucalyptus* wood for pulp has also resulted in the introduction of a second species of *Phoracantha, P. recurva* (Miquel 2008). If such importations continues a number of additional species of this genus, which are mainly related to *Eucalyptus* (Wang 1995), are expected to arrive.

Since their first usage, wood packaging and palettes have constituted an important introduction pathway. The source material spends sufficient time as logs without sanitary controls to be colonized by longhorn beetles. When the wood is turned into packages or palettes, infestation occurs mainly as unnoticed early stages (eggs or first-instar larva). Development continues in the woody material during importation and emergence of adults occurs often unnoticed in warehouses, weeks or months after arrival. This is the case for *A. glabripennis*, *P. hilaris* and *M. alternatus* which may already complete their entire lifecycle before the source wood is processed or destroyed. Wood package is often produced using low quality timber often colonized by longhorn beetle species, which is increasing its potential as a vector.

Other, less significant, introduction pathways have also been identified, yet they typically only transported one or a few individuals which fail to establish. The introduction route is unknown for other species such as *Acanthoderes jaspideus* (Méquignon 1935), *Oxymerus aculeatus* (Alluaud 1935), *Deroplia albida*, and *Phryneta leprosa* (Mifsud and Dandria 2002) but they may be related to the uncontrolled importation of wild plants. Natural range expansion cannot be ruled out for a few species which have a nearby native range, e.g. *Lucasianus levaillantii* (Mayet 1905, Pellegrin and Cocquempot 2001) and *Xylotrechus stebbingi* (Šefrová and Laštůvka 2005) originating from North Africa and the Middle East, respectively.

8.1.7 Ecosystems and habitats invaded in Europe by alien cerambycid species

Although all natural or artificial terrestrial ecosystems and anthropogenic areas which contain trees, bushes or wood products are potentially occupied by alien longhorn beetles, establishment in Europe is concentrated in man-made habitats to date, especially in parks and gardens (Figure 8.1.5). To date, only the two clytine beetles, *Neoclytus acuminatus* and *Xylotrechus stebbingi*, have colonized natural habitats. *X. stebbingi* is very common on *Eucalyptus* cut wood in Crete (Sama 2002) for example and may be related to the polyphagous nature of these two species. Other polyphagous species such as *Anoplophora* spp. also have the potential to live in urban areas, in cultivated lanes (e.g. planted with poplars) as well as in natural forests where potential host plants occur. However, dispersal from man-made habitats to natural forests appears to be a slow process. For the first twenty-two years since its arrival in North America, *A. glabripennis* has been restricted to trees in urban areas until 2008 when it was found in natural forests dominated by *Acer* trees (Haack et al. 2010). Although such a process has not yet been observed in Europe, there is a strong risk that *Anoplophora* spp. will spread to naturally-forested landscapes, if the ongoing eradication attempts in Austria, Germany, France and Italy are unsuccessful.

The expansion of oligophagous species is inevitably more dependant on the presence of suitable host plants. Those using largely- planted trees can spread more easily.

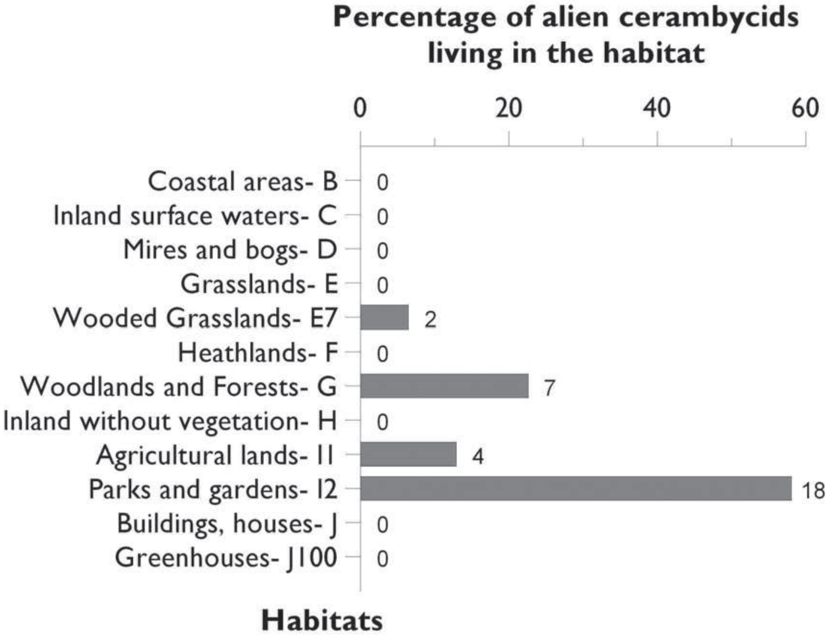

Figure 8.1.5. Main European habitats colonized by the established alien longhorn beetles. The number over each bar indicates the absolute number of alien longhorn beetles recorded per habitat. Note that a species may have colonized several habitats.

Thus, *Phoracantha* spp. that live only in eucalypt trees have colonized ornamental tree plantations in urban areas as well as old plantations such as those found on the Mediterranean islands and in neighbouring countries, and industrial plantations created for paper pulp. Other established species mostly have a distribution restricted to Mediterranean and Atlantic islands. In these areas, anthropogenic ecosystems are mainly colonized. A species of considerable concern with conifer forests is *Monochamus alternatus*, which could potentially become established in coniferous plantations and forests and subsequently transfer the pine wood nematode (Bursaphelenchus xylophilus Steiner & Buhrer, 1934).

8.1.8 Ecological and economic impact of alien cerambycid species

Although there is concern about the potential ecological impact of the invasive longhorn beetles *N. acuminatus* and *X. stebbingi*, there is no measure of their impact on trees or any estimation of possible competitive displacement of the native fauna. The ecological impact of *Anoplophora* species may also be important if they establish in European forests. *Anoplophora* could compete with other arthropods occupying the same niche, but they also create niches for other arthropods that live in tunnels in decaying wood or compete with other saproxylic beetles. The joint introduction and establishment of the Citrus longhorn beetle, *A. chinensis*, and its parasitoid, *Aprostocetus anoplophorae* Delvare, 2004, exemplifies the potential risk of adaptation of imported parasitoids which themselves might not specialise on the native fauna (Delvare et al. 2004).

Although the ecological niche occupied by an alien species may be vacant there remains a risk of secondary infection resulting from their damage. For example, secondary infestation by the pine wood nematode vectored by *Monochamus* spp. (Evans et al. 2008, Kawai Miho et al. 2006) may cause serious impacts to coniferous trees in all landscapes. *M. alternatus* has only been intercepted in Germany and France (Cocquempot 2007, Cocquempot (Unpubl.)); yet the pine wood nematode which it vectors was recorded from Portugal in 1999 (Mota et al. 1999). After having been contained for several years in a limited area, the nematode has spread throughout Portugal, as well as being eradicated following incursions into Spain in 2008 and Madeira in 2009. A novel association with the native species, *M. galloprovincialis* (Villiers 1967) has also been reported. The expansion as well as new introductions of the pine wood nematode could potentially have a substantial level of economic impact in all areas of coniferous cultivation in Europe.

Other economic impacts are mainly associated with ornamental trees in urban areas, cultivated trees such as poplars and eucalypts and nurseries, including these for bonsai production. Studies of *Anoplophora glabripennis* in North America and *A. chinensis* in China indicate the possible scale of economic damage following establishment of these species in a new country or in a plantation, especially of poplar or Citrus trees (Cocquempot et al. 2003, Haack et al. 2010, MacLeod et al. 2002). As a control measure, ornamental trees colonized by invasive longhorns must be eliminated without consideration of their aesthetic value. Eradication measures entail high costs to be borne by local communities or private owners. Special attention is paid to *A. chinensis* necessitating complete removal of trees, including the rootstock (Haack et al. 2010).

Poplars or eucalypt plantations can be highly affected as has already been the case in China (*A. glabripennis* on poplars) and in Spain (*Phoracantha* spp.), where infested trees become unsuitable for pulp and wood exploitation. The Citrus longhorn beetle is also considered as an important risk for all Citrus fruit production in the Mediterranean area and its islands.

The nursery industry is already concerned. There are several examples of introductions or establishments of potentially invasive species such as *Callidiellum rufipenne* and *Anoplophora chinensis*, with the imports of nursery plants. Nurseries can themselves be vectors of aliens when they dispatch their products.

The eradication process established for quarantine species aims to limit introductions although only a few eradications have been officially reported in Europe, e.g. as for *Anoplophora chinensis* in France (Hérard et al. 2006, Hérard and Roques 2009). Phytosanitary interceptions at borders are likely to have prevented a number of introductions and further establishments (e.g., *Monochamus alternatus*, *Trichoferus campestris* in France, *Anoplophora glabripennis* and *A. chinenis* in several countries) (Cocquem-

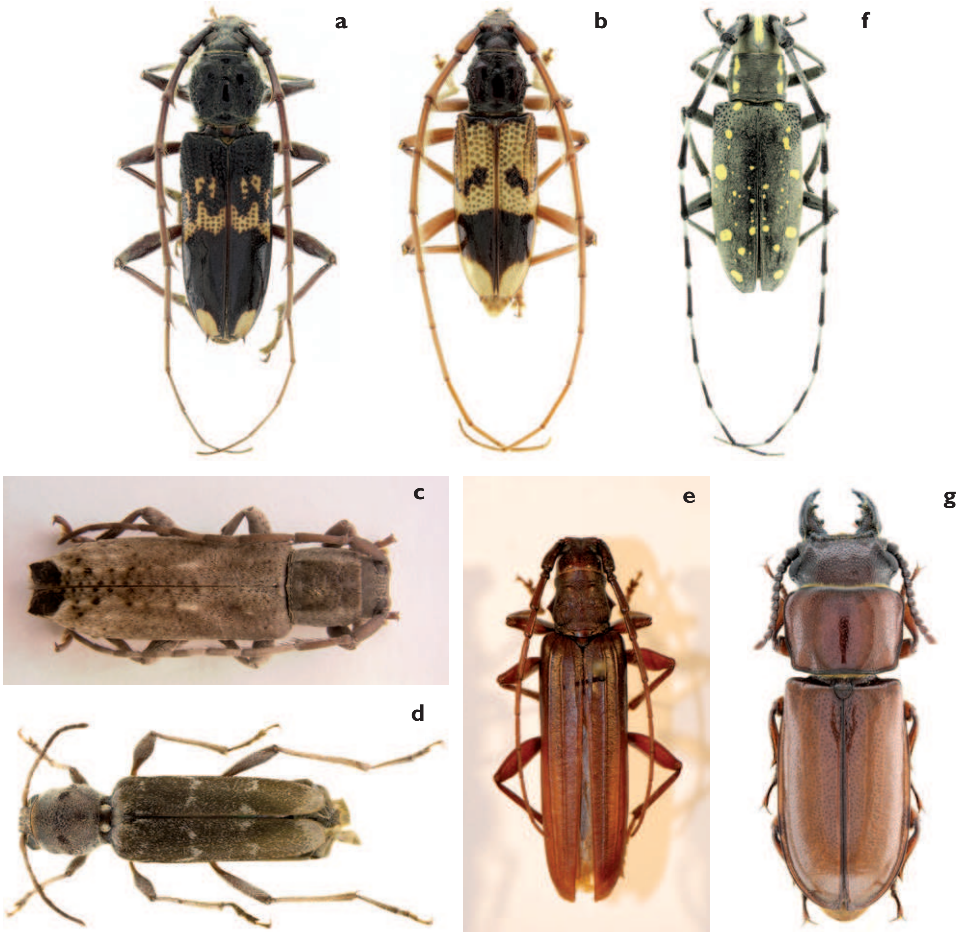

Figure 8.1.6. Adults of some alien longhorn beetle species. **a** *Phoracantha semipunctata* **b** *Phoracantha recurva* **c** *Mimectatina meridiana* (Credit: Christian Cocquempot) **d** *Xylotrechus stebbingi* (Credit: Vítěslav Maňák) **e** *Bardistes cibarius* (Credit: Christian Cocquempot) **f** *Psacothea hilaris* **g** *Parandra brunnea* (a, b, e, f, g: Credit: Henri-Pierre Aberlenc).

pot 2007) whilst at the same time, several non-quarantine species not submitted to importation controls have become established (e.g., *Xylotrechus stebbingi*, *Phoracantha semipunctata*, *Neoclytus acuminatus*). This illustrates the importance of quarantine species lists, which should be preventive and not only curative to be most effective.

Human-mediated dispersal should also be tightly controlled during the eradication process. Without due respect for control obligations, eradication can fail. For example, the long delay by Italian authorities in applying control measures and strong management measures against *Anoplophora chinensis* (EPPO 2009, Jucker et al. 2007) or inadvertent movement of untreated wood material for *A. glabripennis* in New-York (Haack et al. 1997) are examples of ineffective eradication efficacy.

8.1.9 Expected trends

The combination of increasing volumes of trade, the increased speed of import of potential vectors, the diversity of sources and sites for introduction is likely to result in increasing invasion risk (Cocquempot 2007). All recently established species alien *to* Europe have been intercepted too late after their introduction and have been outside official institutional controls. These factors make it increasingly difficult for rapid eradication after initial arrival. Effective monitoring of each point of possible entry is unfeasible when the key pathways identified here have different vectors and locations of arrival (e.g. airports, harbours, stations, lorry parks), and there are major difference in the quality of phytosanitary controls between European countries, particularly following the enlargement of the EU. The risk depends on volume and diversity of vector material imported, and subsequently there is greatest risk in countries such as the UK, France, Spain, Italy, Netherlands, Belgium and Germany. The case of *Anopolophora glabripennis* in North America and Europe clearly demonstrates the possibility of spread in our continent; such detailed assessment is required for all potentially invasive longhorn beetles (MacLeod et al. 2002).

According to Worner (2002), progress in the knowledge of invasion processes and associated preventive measures have not been followed by actions since the late 1980's. Preventive methods are still routinely applied, e.g. the application of ISPM 15 (International Standard for Phytosanitary Measures No.15), which set standards for heat treatment and fumigation of wood product materials used in international trade is likely to limit the arrival of longhorn beetles related to these materials although a few have been found to survive (Haack et al. 2010). However, this method is not uniformly applied to all imported living trees, shrubs plants for planting or bonsais. Thus, a high number of imported bonsais or other nursery trees infested with *Anoplophora chinensis* are still discovered (Hérard and Roques 2009). Although importation controls could be improved, they will never offer full protection. Further, controls which reduce the risk of introduction are mainly restricted to quarantine species. Post-interception or controls at importation points should be extended to all the potential pests posing risk and not be restricted to quarantine species already intercepted, introduced or established.

References

Adachi I (1990) Population studies of *Anoplophora malasiaca* adults (Coleoptera: Cerambycidae) in a Citrus grove. *Research Population Ecology* 32: 15–32.

Adlbauer K (2006) personnal communication.

Allenspach V (1973) *Insecta Helvetica 3 – Coleoptera Cerambycidae*. Züric, Switzerland: Fotorotar AG. 216 pp.

Alluaud C (1935) Les Coléoptères des îles Salvages. *Revue française d'Entomologie* 2: 35–44.

Althoff J, Danilevsky ML (1997) *A Check-List of Longicorn Beetles* (*Coleoptera, Cerambycoidea*) *of Europe*. Ljubljana, Slovenia: Slovensko Entomološko Društvo štefana Michielija, 1–64.

Bahillo P, Iturrondobeitia-Bilbao JC (1995) Primera cita de *Callidiellum rufipenne* (Motschulsky, 1860) para la Península Ibérica (Coleoptera: Cerambycidae). *Boletín de la Asociación española de Entomología* 19: 204.

Bercedo P, Bahillo P (1998) *Phoracantha recurva* (Coleoptera: Cerambycidae): Una nueva plaga en los eucaliptales españoles. *Boletín de la Sociedad Entomológica Aragonesa* 23: 52.

Bercedo P, Bahillo P (1999) Primera cita para Europa de *Phoracantha recurva* Newman, 1840 (Coleoptera, Cerambycidae). *Estudios del Museo de Ciencias Naturales de Alava* 14: 169–174.

Berger P (1992) Présence de *Phoracantha semipunctata* F. dans le sud de la France : une menace pour les eucalyptus (Coleoptera Cerambycidae). *Bulletin mensuel de la Société Linnéenne de Lyon* 61: 301–304.

Bertolini S (1872) *Catalogo sinonimico e topografico dei Coleotteri d'Italia*. Firenze : Tipografia Cenniniana, 263 pp.

Bijaoui R (1980) Notes de chasses et observations diverses : *Neoclytus acuminatus* (Col. Cerambycidae) dans le Tarn. *L'Entomologiste* 36: 268.

Borges PAV, Cunha R, Gabriel R, Frias Martins A, Silva L and Vieira V (eds) *A list of the terrestrial fauna* (*Mollusca and Arthropoda*) *and flora* (*bryophyta, Pteridophyta and Spermatophyta*) *from the Azores*. Direccao Regional do Ambiente and Universidade das Açores, 317 pp.

Bosmans B (2006) *Phoracantha recurva* (Coleoptera: Cerambycidae) found in a cluster of bananas *Phegea* 34: 105.

Brustel H, Berger P, Cocquempot C (2002) Catalogue des Vesperidae et des Cerambycidae de la faune de France (Coleoptera). *Annales de la Société entomologique de France* 38: 443–461.

Bytinski-Salz H (1956) The Cerambycidae of Israel. *Bulletin of the Research Council of Israel* 5B: 207–226.

Cadahia D (1980) Proximidad de dos nuevos enemigos de los Eucalyptus en España. *Boletín del Servicio de Plagas forestales* 6: 165–192.

Campadelli G, Sama G (1988) Prima segnalazione per l'Italia di cerambicide giapponese: *Callidiellum rufipenne* Motchulsky. *Bollettino dell'Istituto di Entomologia "Guido Grandi" della Universita degli Studi di Bologna* 43: 69–73.

Carter M, Smith M, Harrison R (2009) Genetic analyses of the Asian longhorned beetle (Coleoptera, Cerambycidae, *Anoplophora glabripennis*), in North America, Europe and Asia. *Biological Invasions*. doi 10.1007/s10530-009-9538-9

Cavalcaselle B (1983) Osservazioni sulla diffusione di *Phoracantha semipunctata* F. in Sardegna, Sicilia e nell'Italia centro-meridionale. *Atti XIII Congresso Nazionale Italiano di Entomologia, Sestriere-Torino*, 455–464.

Černý Z (2002) A contribution to the understanding of Beetles of the family Coleoptera: Cerambycidae in Greece. *Studie a Zprávy Okresniho Muzea Praha-Vychod* 14: 3–26.

Chikatunov V, Kravchenko, Dorchin Y, Müller G (2006) The xylophagous beetles (Buprestidae, Lyctidae, Bostrichidae, Anobiidae, Cerambycidae, Scolytidae, Platypodidae) collected in the Israeli light trap survey and their association with the major phyto-geographical zones of Israel. Esperiana. *Buchreiche zur Entomologie* 12: 313–320.

Chikatunov V, Pavlicek T, Nevo E (1999) Coleptera of "Evolution Canyon". Lower Nahal Oren, Mount Carmel, Israel. *Pensoft Series faunistica* 14: 1–174.

Cocquempot C (1993) Notes de chasse et Observations diverses – Nouvelle extension pour *Phoracantha semipunctata* (F.) (Col. Cerambycidae). *L'Entomologiste* 49: 37.

Cocquempot C (2007) Alien longhorned beetles (Coleoptera Cerambycidae): Original interceptions and introductions in Europe, mainly in France, and notes about recently imported species. *Redia* 89: 35–50.

Cocquempot C, Debreuil M (2006) *Xylotrechus stebbingi* Gahan 1906 et *Phoracantha semipunctata* (Fabricius, 1775): historique de l'expansion française de deux envahisseurs (Coleoptera Cerambycidae). *Rutilans* 9: 85–89.

Cocquempot C, Grousset C, Pellegrin D (2007) *Distribution française de Lucasianus levaillantii* (*Lucas, 1846*) *et des sous-espèces d'Icosium tomentosum* (*Lucas, 1854*) (*Coleoptera Cerambycidae*). Rutilans 10: 35–39.

Cocquempot C, Hérard F, Reynaud P (2003) Les longicornes asiatiques *Anoplophora glabripennis* et *Anoplophora chinensis*, une menace sérieuse pour l'arboriculture fruitière, les plantes d'ornement et les forêts françaises. *Phytoma – La Défense des Végétaux* 561: 24–28.

Cocquempot C, Sama G (2004) L'expansion circumméditerranéenne de *Phoracantha recurva* (Newman, 1840) (Coleoptera, Cerambycidae). *L' Entomologiste* 59: 209–214.

Colombo M, Limonta L (2001) *Anoplophora malasiaca* Thomson (Coleoptera Cerambycidae Lamiinae Lamiini) in Europe. *Bollettino di Zoologia agraria e di Bachicoltura II Ser* 33: 65–68.

Dauber D, Mitter H (2001) Das erstmalige Auftreten von *Anoplophora glabripennis* Motschulsky 1853 auf dem europaïschen Festland (Coleoptera: Cerambycidae: Lamiinae). *Beiträge zur Naturkunde Oberösterreichs* 10: 503–508.

De Fluiter HJ (1950) *Monochamus* (*Monohammus*) *galloprovincialis* Oliv. (Col.Cerambicidae). *Entomologische Berichten* 13: 135–136.

Delvare G, Bon M-C, Hérard F, Cocquempot C, Maspero M, Colombo M (2004) Description of *Aprostocetus anoplophorae* n. sp. (Hymenoptera: Eulophidae), a new egg parasitoid of the invasive pest *Anoplophora chinensis* (Förster) (Coleoptera: Cerambycidae). *Annales de la Société entomologique de France* 40: 227–233.

Demelt C (1974) Zusammenfassung und revision der cerambycidenfauna der Canarischen Inseln. *Nouvelle Revue d'Entomologie* 4: 227–236.

Dioli P, Vigano C (1990) Presenza in Valtellina di un cerambice nuovo per la Fauna italiana: *Xylotrechus stebbingi* Gahan, 1906 (Insecta, Coleoptera, Cerambycidae). *Il Naturalista Valtellinese* 1: 7–10.

Duffy EAJ (1953a) *A Monograph of the immature stages of British and imported Timber Beetles* (*Cerambycidae*). London: British Museum (Natural History). 350 pp.

Duffy EAJ (1953b) *Trinophylum cribratum* Bates (Col., Cerambycidae). A new Indian pest of British timber yards. *Entomologist's Gazette* 4: 254–264.

EPPO (2004). First report of *Anoplophora glabripennis* in Germany. *EPPO Reporting Services* 5: 2004/072.

EPPO (2006). Recent interceptions of *Anoplophora* species in United Kingdom. *EPPO Reporting Services* 5: 2006/098.

EPPO (2008) Premier signalement de *Saperda candida* en Allemagne: addition à la Liste d'Alerte de l'OEPP. *EPPO Reporting services 7*: 2008/139.

EPPO (2009a) De plus amples détails sur le foyer d'*Anoplophora chinensis* à Roma (IT). *EPPO Reporting Services* 3: 2009/048.

EPPO (2009b) *Anoplophora chinensis* found on *Cornus* and *Crataegus* in the Netherlands. *EPPO Reporting Services* 9: 2009/173

Evans S, Evans HF, Ikegami M (2008) Modeling PWN-Induced Wilt Expression: A Mechanistic Approach. In: Mota M, Vieira P (Eds) *Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems*. The Netherlands: Springer Science+Business Media B.V., 259–278.

EPPO (2010) *Anoplophora chinensis* found again in the Netherlands. *EPPO Reporting Services* 2 : 2010/025

Fauna Europaea. http://www.faunaeur.org.

Fauvel (1884) Les Longicornes Gallo-Rhénans (suite) - Catalogue. *Revue d'Entomologie* 3: 317–390.

Frank H (2002) Pathways of arrival. In: Hallman GJ, Schwalbe CP *Invasive Arthropods in Agriculture: Problems and Solutions.* Enfield, UK: Sciences Publishers Inc., 71–86.

Friedman ALL, Rittner O, Chikatunov VI (2008) Five new invasive species of longhorn beetles (Coleoptera: Cerambycidae) in Israel. *Phytoparasitica* 36: 242–246

Gilmour EF (1948) *Trinophylum cribratum* Bates (Col., Cerambycidae) new to Britain.*The Entomologist's monthly Magazine*, 84: 12–16.

Haack RA, Poland TM, Gao RT (2000) The United States experience with the exotic Cerambycid *Anoplophora glabripennis*: Detection, Quarantine, and Control. In: *Quarantine pests, risks for the forestry sector and their effects on foreign trade. Proceedings on CD-Room of Silvotecna Conference 14, 27–28 June 2000*. Concepcion, Chile: CORMA. 12 pp.

Haack RA, Law KR, Mastro VC, Ossenbruggen SH, Raimo BJ (1997) New York's battle with the Asian Long-Horned Beetle. *Journal of Forestry* 95: 11–15.

Haack RA, Hérard F, Sun JH, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorn beetle: A worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Hérard F, Ciampitti M, Maspero M, Krehan H, Benker U, Boegel C, Schrage R, Bouhot-Delduc L, Bialooki P (2006) *Anoplophora* species in Europe: infestations and management processes. *Bulletin OEPP/EPPO Bulletin* 36: 470–474.

Hérard F, Maspero M, Ramualde N, Jucker C, Colombo M, Ciampitti M, Cavagna B (2009) *Anoplophora glabripennis* - Eradication programme in Italy (April 2009). http://www.eppo.org/QUARANTINE/anoplophora_glabripennis/ANOLGL_IT.htm.

Hérard F, Roques A (2009) Current status of *Anoplophora* spp. in Europe and an update on suppression efforts. In: Gottschalk KW (Ed) Proceedings of the 20th U.S. 20th USDA Interagency Research Forum on Invasive Species Annapolis, Maryland, 13- 16 January 2009. Gen. Tech. Rep. NE-337. Morgantown, USA: USDA Forest Service, Northeastern Research Station.

Heyrovský L (1930) Entomologické Prírucky XV. Catalogus Coleopterum Cechosloveniae – 1. Cerambycidae. *Casopis Ceskoslovenské spolecnosti Entomologické* 26–27: 1–61.

Heyrovský L (1951) Catalogus Coleopterum Cechosloveniae. Supplementum. Cerambycidae (Tesaríci). *Casopis Cekqslovenské spolecnosti Entomologické*, 48: 43–53.

Heyrovský L, Sláma G (1992) Tesaríkovití – Coleoptera, Cerambycidae. Zlín, Czech Republic: Kabourek. 367pp.

Horion A (1974) *Faunistik der mitteleuropäischen Käfer 12: Cerambycidae – Bockkäfer*. Überlingen-Bodensee. 228 pp.

Hunt T, Bergsten J, Levkanicova Z, Papadopoulou A, Saint-John O, Wild R, Hammond P M, Ahrens D, Balke M, Caterino M S, Gómez-Zurita J, Ribera I, Barraclough TG, Bocakova M, Bocak L, Vogler AP (2007) A Comprehensive Phylogeny of Beetles Reveals the Evolutionary Origins of a Super-radiation. *Science*, 318: 1913–1916.

Ilić N (2005) [*Longhorn beetles* (*Coleoptera, Cerambycidae*) *from Serbia.* Faunistic review] (in Serbian) Belgrade: SZGR "Joksimović".180pp.

Jucker C, Tantardini A, Colombo M (2006) First record of *Psacothea hilaris* (Pascoe) in Europe (Coleoptera Cerambycidae lamiinae Lamiini). *Bollettino di Zoologia agraria e di Bachicoltura* 38: 187–191.

Jucker C, Maspero M, Colombo M (2007) Principali fitofagi in ambiente urbano e loro contenimento. *Informatore fitopatologico*: 22–25.

Kawai Miho, Etsuko Shoda-Kagaya, Tadashi Maehara T, Zhou ZH, Lian CL, Iwata RT, Yamane A, Hogetsu T (2006). Genetic structure of pine sawyer *Monochamus alternatus* (Coleoptera: Cerambycidae) populations in Northeast Asia: consequences of the spread of Pine Wilt Disease. *Environmental Entomology* 35, 569–579.

Köhler F (2000) Erster Nachtrag zum „Verzeichnis der Käfer Deutschlands". *Entomologische Nachrichten und Berichte* 44: 60–84.

Komazaki S, Sakagami Y (1989) Capture-Recapture Study on the Adult Population of the White Spotted Longicorn Beetle, *Anoplophora malasiaca* (Thomson) (Coleoptera: Cerambycidae) in a Citrus Orchard. *Applied Entomology and Zoology,* 24: 78–84.

Korcynski I (1985) The Biology of *Nathrius brevipennis* (Muls.) (Coleoptera, Cerambycidae) in Poland. *Polskie Pismo Entomologiczne* 55: 73–78.

Lawrence JF, Newton AF (1995) Families and subfamilies of Coleoptera (with selected genera, notes, references and data of family-group names. In: Pakaluk J, Ślipiński SA (Eds) *Biology, Phylogeny, and Classification of Coleoptera*. Papers celebrating the 80th Birthday of Roy Crowson. Warzawa: Muzeum i Instytut Zoologii PAN, 779–1006.

Lemos-Perreira AB (1978) Sobre o aparecimento em Portugal de um Coleóptero Longicórnio exótico, do género *Acrocinus*. *Publicações do Instituto de Zoologia «Dr. Augusto Nobre», Faculdade de Ciências do Porto* 138: 1–13.

Linnaeus C von (1758) *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. 10th Edition. Holmiæ, Impensis direct. Laurentii Salvii (Salvius)

Lucht WH (1987) *Die Käfer Mitteleuropas. Katalog*. Krefeld, Germany: Goecke & Evers Verlag. 342pp.

MacLeod A, Evans HF, Baker RHA (2002) An analysis of pest risk from an Asian longhorn beetle (*Anoplophora glabripennis*) to hard wood trees in the European community. *Crop Protection*, 21: 635–645.

Maspero M, Cavalieri G, D'Angelo G, Jucker C, Valentini M, Colombo M, Hérard F, Lopez J, Ramualde N, Ciampitti M, Caremi G, Cavagna B (2007a) *Anoplophora chinensis* - Eradication programme in Lombardia (Italy) http://www.eppo.org/QUARANTINE/anoplophora_chinensis/chinensis_IT_2007.htm.

Maspero M, Jucker C, Colombo M (2007b) First record of *Anoplophora glabripennis* (Motschulsky) (Coleoptera Cerambycidae Lamiinae Lamiini) in Italy. *Bollettino di Zoologia agraria e di Bachicoltura*, Serie II 39: 161–164.

Mayet V (1905) Le *Lucasianus levaillanti* Lucas (Col.), sa découverte en France et ses mœurs. *Bulletin de la Société entomologique de France*: 277–279.

Mazzeo G, Siscaro G (2007) Presenza di *Phoracantha recurva* su eucalipto in Sicilia. *Informatore fitopatologico*: 35–37.

Mendizábal M (1944) Cerambícidos de interés agricola. Boletín de Patología vegetal y Entomología agrícola 11: 463–476.

Méquignon A (1935) Voyage de MM. L. Chopard et A. Méquignon aux Açores (aoùt- septembre 1930) – VIII. Coléoptères américains acclimatés aux Açores. *Bulletin de la Société entomologique de France* 13: 203–204.

Mifsud D (2002) Longhorns beetles of the Maltese Islands (Coleoptera, Cerambycidae). *The Central Mediterranean Naturalist* 3: 161–168.

Mifsud D, Booth R (1997) Further contributions to the knowledge of the Longhorn Beetles (Coleoptera: Cerambycidae) of the Maltese Islands. *The Central Mediterranean Naturalist* 2: 35–36.

Mifsud D, Dandria D (2002) Introduction and establishment of *Phryneta leprosa* (Fabricius) (Coleoptera, Cerambycidae) in Malta.*The Central Mediterranean Naturalist* 3: 207–210.

Miquel ME (2008) The presence of *Phoracantha recurva* (Newman) (Coleoptera: Cerambycidae) in France and how to differentiate if from *P. semipunctata*. *British Journal of Natural History* 21: 193–194.

Mota MM, Braasch H, Bravo MA, Penas AC, Burgermeister W, Metge K and Sousa E (1999) First report of *Bursaphelenchus xylophilus* in Portugal and in Europe. *Nematology* 1: 727–734.

Napp DS (1994) Phylogenetic relationships among the subfamilies of Cerambycidae (Coleoptera – Chrysomeloidea). *Revista Brasileira de Entomologia* 38: 265–419.

Nolte O, Krieger D (2008) Nachweis von *Saperda candida* Fabricius 1787 auf Fehmarn – eine weitere, bereits in Ansiedlung befindliche, eingeschleppte Käferart in Mitteleuropa. *DgaaE-Nachrichten* 22: 133–136.

Nüssler H (1961) Ein beständiges Vorkommen des nearktischen Bockkäfers *Parandra brunnea* Fabr. (Col. Cerambycidae) in Deutschland. *Abhandlungen und Berichte aus dem Staatliches Museum für Tierkunde in Dresden* 26: 125–130.

Orousset J (1984) *Phoracantha semipunctata* Fabr., un ravageur des eucalyptus présent en Corse (Col. Cerambycidae). *Nouvelle Revue d'Entomologie* 1: 322.

Orousset J (1991) Présence aux Îles Canaries du ravageur des Eucalyptus *Phoracantha semipunctata* (Col. Cerambycidae). *Nouvelle Revue d'Entomologie* 8: 76.

Orousset J (2000) *Phoracantha recurva* Newman sera-t-il à ajouter à la faune de France ? (Coleoptera, Cerambycidae). *Le Coléoptériste* 39: 129–131.

Özdikmen H (2008) A nomenclatural act: some nomenclatural changes on palaearctic longhorned beetles (Coleoptera: Cerambycidae). *Munis Entomology and Zoology* 3: 707–715.

Palmeri V, Campolo O (2006) Sulla presenza di *Phoracantha recurva* e *Phoracantha semipunctata* F. (Coleoptera Cerambycidae) in Calabria. *Bollettino di Zoologia agraria e di Bachicoltura* 38: 251–254.

Pellegrin D (1990) *Icosium tomentosum* Lucas, espèce nouvelle pour la France continentale (Col. Cerambycidae Cerambycinae). *L'Entomologiste*, t. 46 (4): 167–169.

Pellegrin D, Cocquempot C (2001) Réhabilitation de la présence en France de *Lucasianus levaillanti* (Lucas, 1849) et nouvelles données géographiques. *Biocosme mésogéen* 18: 27–31.

Pérez Moreno I (2001) *Plagas introducidas em España peninsular em la segunda mitad del siglo XX*. ARACNET 4 http://entomologia.rediris.es/aracnet/num4/entomap/index.htm.

Picard F (1937) Sur les Cérambycides de Madère et des îles voisines. *Compte rendu sommaire des Séances de la Société de Biogéographie* 13: 70–72.

Pil N, Stojanović D (2005) Some rare longhorn beetles (Coleoptera: Cerambycidae) without Protection on the national level found on Mt. Fruška Gora, Serbia. *Archives of Biological Science Belgrade* 57: 137–142.

Plavilstshtikov NN (1934) *Bestimmungs-Tabellen der europaïschen Coleopteren. 112 Heft. Cerambycidae III. Teil. Cerambycinae: Cerambycini II1* (*Callichromina, Rosaliina, Callidiina*), Troppau, Germany: Verlag Edmund Reitter. 230pp.

Plaza Lama J (1990) Primera cita para la fauna ibérica de *Lucasianus levaillanti* (Lucas, 1849) (Col. Cer.). *Boletín del Grupo Entomológico de Madrid* 5: 73–75.

Reineck G (1919) Die Insekten der Mark Brandenburg. 2. Coleoptera. Cerambycidae. *Beiheft der Deutsche Entomologische Zeitschrift* 63: 1–92.

Rossem G. van, van de Bund CF, Burger HC, de Goffau LJW (1981) Bijzondere aantastingen door insekten in 1980. *Entomologische Berichten* 41: 84–87.

Ruiz JL, Barranco P (1998) *Phoracantha recurva* Newman, 1840, nueva especie plaga para la Región Mediterránea (Coleoptera: Cerambycidae). *Boletín de la Asociación Española de Entomología* 22: 227–228.

Sama G (1984) *Fauna d'Italia Vol. XXV. Coleoptera Cerambycidae, Catalogo topographico e sinonimico*. Bologna, Italia: Edizioni Calderini. 216 pp.

Sama G (2002) *Atlas of the Cerambycidae of Europe and Mediterranean area. Vol 1: Northern, Western, Central and Eastern Europe.* Zlín, Czech Republic : Kabourek. 173 pp.

Sama G (2006a) Notes on *Taeniotes scalaris* (Fabricius, 1781) and *T. cayennensis* (Thomson, 1859) (Coleoptera: Cerambycidae) in the Azorean Archipelago. *Boletín de la Sociedad Entomológica Aragonesa* 39: 231–234.

Sama G (2006b) Taxonomical remarks on *Xylotrechus smei* (Castelnau & Gory, 1841) and *X. stebbingi* Gahan, 1906 and their distribution in Western Palaearctic region. *Doriana* 7: 1–6.

Sama G, Bocchini R (2003) *Phoracantha recurva* (Newman, 1840) (Insecta Coleoptera Cerambycidae), prima segnalazione per la fauna italiana.*Quaderno di Studi e Notizie di Storia naturale della Romagna* 18: 168.

Sama G, Buse J, Orbach E, Friedman ALL, Rittner O, Chikatunov V (2010) A new catalogue of the Cerambycidae (Coleoptera) of Israel with notes on their distribution and host plants. *Munis Entomology and Zoology* 5: 1–51.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Sama G, Cocquempot C (1995) Note sur l'extension européenne de *Xylotrechus stebbingi* Gahan, 1906 (Coleoptera, Cerambycidae, Clytini). *L'Entomologiste* 51: 71–75.

Schembri S, Sama G (1986) The Cerambycidae of the Maltese Islands (Coleoptera). *Bollettino della Società entomologica italiana* 118: 93–100.

Schmidt G, Schmidt HU (1990) Ein ungewöhnlicher "Gast" aus einem Bonsai- Bäumchen: *Anoplophora malasiaca* Thoms. (Coleoptera: Cerambycidae). *Mitteilungen des Internationalen Entomologischen Vereins* 15: 69–75.

Serrano ARM (1982) Contribuciao para o conhecimato do poro amerto, distribuciao e oviger dos Coleopteros do Archipelago dos Açores. *Boletim do Museu Municipal do Funchal* 34: 67–104.

Sliwinski Z (1958) *Nathrius brevipennis* (Muls.) Bosq. a new species of beetle (Coleoptera, Cerambycidae) for fauna Polands. *Polskie Pismo Entomologiczne* 28: 129–131.

Smith MT, Bancroft J, Li G, Gao R, Teale S (2001) Dispersal of *Anoplophora glabripennis* (Cerambycidae). *Environmental Entomology* 30: 1036–1040

Speight MCD (1988) The Irish Cerambycid fauna (Coleoptera : Cerambycidae). *Bulletin of the Irish biogeographical Society* 11: 41–76.

Sýkorová M (2008) *Molecular phylogeny of subfamilies Spondylidinae and Lepturinae based on mitochondrial 16S rDNA, BCc.* PhD Thesis. České Budějovice, Czech Republic: Faculty of Science, University of South Bohemia. 34pp.

Szeoke K, Hegyi T (2002) A szolo uj kartevoje az amerikai darazscincer (*Neoclytus acuminatus* Olivier). [A new grapevine pest: redheaded ash borer (*Neoclytus acuminatus* Olivier)]. *Novenyvedelem Majus* 38: 268–269.

Tassi F (1969) Un longicorne australiano per la prima volta in Italia (Col. Cerambycidae). *Bolletino dell' Associazione Romana di Entomologia* 24: 69–71.

Teunissen (2002) Waarnemingen van *Xylotrechus stebbingi* in Griekenland. Een Aziatische wespenboktor die zich in korte tijd heeft verbreid in het Middellandsee-Zeegebied. *Entomologische Berichten* (*Amsterdam*) 62: 57–58.

Tomiczek C, Hoyer-Tomiczek U (2008). Biology Studies Relevant to the Vector Role of *Monochamus* Species for PineWood Nematode. In: Mota M, Vieira P (2008) *Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems*. Dordrecht, The Netherlands: Springer, 215–221.

Verdugo Páez AV (2004) Los cerambícidos de Andalucía (Coleoptera: Cerambycidae). Córdoba, Spain: Sociedad Andaluza de Entomología. Monográfico 1. 148 pp.

Villiers A (1967) Coléoptères Cérambycides de l'île de Chypre. *L'Entomologiste* 23: 63–64.

Villiers A (1979) Un nouveau Clytini en France ? *L'Entomologiste* 35: 144.

Vincent R (2007) *Catalogue des Coléoptères du département de la Saône-et-Loire* (*F-71*). *Volume I: Cerambycidae.* Terre Vive, Supplément Hors-Série: 183 pp.

Vives E (1995) Notas sobre longicornios ibéricos (V). Cerambícidos importados o aclimatados en la Península Ibérica (Coleoptera, Cerambycidae). Zapateri, *Revista aragonese de Entomologia* 5: 165–174.

Wang Q (1995) A Taxonomic Revision of the Australian Genus *Phoracantha* Newman (Coleoptera: Cerambycidae). *Invertebrate Taxonomy,* 9: 865–958.

Weidner H (1973) Insekten als Schädlinge an Drogen in Apotheken un Drogerien. *Anzeiger für Schädlingskunde und Pflanzen- und Umweltschutz vereinigt mit Schädlingsbekämpfung* 46: 177–180.

Weyers M (1875) Communication sur *Leptidea brevipennis* à Bruxelles. *Annales de la Société entomologique de Belgique, Comptes rendus des Séances* 18: 86–87.

Weyers M (1876) Communication à propos de Longicornes nouveaux pour la faune belge. *Annales de la Société entomologique de Belgique, Comptes rendus des Séances* 19: 65.

Wiel P van der (1956) Bijdrage tot de kennis der Nederlandse kevers, IV. Tijdschrift voor Entomologie, t. 99 (1–2): 1–21.

Winkler A (1932) *Catalogus Coleopterum regionis palaearcticae*. Wien: Albert Winkler Verlag: 1135–1226.

Wittenberg R (Ed) (2005) An inventory of alien species and their threat to biodiversity and economy in Switzerland. Délemont, Switzerland: CABI Bioscience Switzerland Centre, Report to Swiss Agency for Environment, Forest and Landscape. 417 pp.

Wollaston TV (1863) On the Canarian Longicorns. *Journal of Entomology* 8: 99–110.

Worner SP (2002) Predicting the invasive potential of exotic insects. In: Hallman GJ, Schwalbe CP *Invasive Arthropods in Agriculture: Problems and Solutions.* Enfield, UK: Sciences Publishers Inc., 119–137.

Table 8.1.1. List and characteristics of the Cerambycidae species alien to Europe. Status: A: Alien to Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II).

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Acanthoderes jaspidea Germar, 1824	A	phyto-phagous	Brazil	1880, PT-AZO	PT-AZO	I2	*Acacia, Albizzia*	Borges et al. 2005, Méquignon 1935, Serrano 1982
Acrocinus longimanus (Linnaeus, 1758)	A	phyto-phagous	Brazil	1977, PT	PT, PT-MAD	I2	Moraceae, Apocynaceae	Lemos-Perreira 1978 , Vives 1995
Anoplophora chinensis (Förster, 1848) (=*A. malasiaca* Thompson, 1865)	A	phyto-phagous	China South-Central	2000, IT	IT, NL	FB, FA, I2, G	*Acer, Betula, Carpinus Citrus, Corylus, Rosa* and deciduous shrubs (polyphagous)	Cocquempot 2007, Colombo and Limonta 2001, 2009a, EPPO 2009b, Evans et al. 2008, Hérard et al. 2006
Anoplophora glabripennis (Motschulsky, 1853)	A	phyto-phagous	China South-Central	2001, AT	AT, DE, FR, IT	FB, FA, I	*Acer, Aesculus, Betula, Carpinus, Fagus, Populus, Salix*	Carter et al. 2009, Cocquempot 2007, Cocquempot et al. 2003, Dauber and Mitter 2001, EPPO 2004, Hérard et al. 2006, 2009
Callidiellum rufipenne (Motschulsky, 1860)	A	phyto-phagous	Eastern Asia, Japan	1906, FR	ES, FR, IT	FA, FB, G1, G5, J4	Cupressaceae (*Cupressus macrocarpa*)	Bahillo and Iturrondobeitia 1995, Campadelli and Sama 1988, Cocquempot 2007
Chlorophorus annularis (Fabricius, 1787)	A	phyto-phagous	Asia-Temperate	1991, ES	ES	G	Bamboo	Vives 1995
Cyrthognathus forficatus (Fabricius, 1792)	A	phyto-phagous	Africa	1872, MT	MT	U	Unknown	Bertolini 1872
Derolus mauritanicus Buquet, 1840	A	phyto-phagous	Northern Africa	1884, FR	ES ?, FR ?	E7, F5, F8, FB, I2, X11	*Nerium oleander*	Brustel et al. 2002, Fauvel 1884, Mendizábal 1944, Verdugo 2004

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Deroplia albida (Brullé, 1838)	A	phyto-phagous	Canary Islands	1988, ES	ES	E7, F6, FB, G5	*Pelargonium*	Vives 1995
Lucasianus levaillantii (Lucas, 1846)	A	phyto-phagous	Northern Africa	1905, FR	ES, FR, PT	FA, G, FB	*Cupressus*	Brustel et al. 2002, Cocquempot et al. 2007, Mayet 1905, Pellegrin and Cocquempot 2001, Plaza Lama 1990, Vives 1995
Neoclytus acuminatus (Fabricius, 1775)	A	phyto-phagous	South-Central U.S.A.	1908, IT	CH, CZ, DE, FR, HR, HU, IT, ME, PT-MAD, RS, SI	FB, G, G1, G5, I2, X11	*Ulmus, Fraxinus, Juglans*	Bijaoui 1980, Brustel et al. 2002, Cocquempot 2007, Heyrovský 1951, Ilić 2005, Picard 1937, Pil and Stojanović 2005, Reineck 1919, Sama 1984, Tassi 1969, Villiers 1979, Winkler 1932, Wittenberg 2005
Oxymerus aculeatus lebasi Dupont, 1838	C	phyto-phagous	Unknown	Unknown	ES-CAN	U	*Calophyllum*	Alluaud 1935
Parandra brunnea (Fabricius, 1789)	A	phyto-phagous	North America	1916, DE	DE	G, J1	*Tilia, Populus,* deciduous trees	Grämer 1961, Nüssler 1961
Phoracantha recurva Newman, 1840	A	phyto-phagous	Australia	1992, IT	ES, GR, IL, IT, IT-SAR, IT-SIC, MT, PT	G1	*Eucalyptus*	Bercedo and Bahillo 1998, Bercedo and Bahillo 1999, Černý 2002, Cocquempot 2007, Cocquempot and Sama 2004, Friedman et al. 2008, Mazzeo and Siscaro 2007, Mifsud 2002, Miquel 2008, Orousset 2000, Palmeri and Campolo 2006, Pérez Moreno 2001, Ruiz and Barranco 1998, Sama and Bocchini 2003, Sama et al. 2010, Wang 1995

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Phoracantha semipunctata (Fabricius, 1775)	A	phyto-phagous	Australia	1948, IL	CY, FR, FR-COR, ES, ES-CAN, GR, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-MAD	FB, G, G1, G5, I2, X11	*Eucalyptus*	Berger 1992, Brustel et al. 2002, Cadahia 1980, Cavalcaselle 1983, Černý 2002, Cocquempot 1993, Cocquempot 2007, Cocquempot and Sama 2004, Mifsud and Booth 1997, Orousset 1984, Orousset 1991, Sama et al. 2010, Teunissen 2002, Vives 1995, Wang 1995
Phryneta leprosa (Fabricius, 1775)	A	phyto-phagous	South Tropical Africa	1997, FR	FR, MT	G	*Morus nigra*	Mifsud and Dandria 2002, Vincent 2007
Taeniotes cayennensis Thomson, 1859	A	phyto-phagous	Central America	1858, PT	PT-AZO	U	Tropical trees	Sama 2006a
Trinophylum cribratum (Bates, 1878)	A	phyto-phagous	India	Unknown	GB	I2	Deciduous trees, *Larix*, *Pinus* (polyphagous)	Duffy 1953b, Gilmour 1948
Xylotrechus stebbingi Gahan, 1906	A	phyto-phagous	Central Asia	1990, IT	CH, CY, DE, FR, GR, GR-CRE, GR-NEG, GR-SEG, IL, IT, IT-SAR	FB, G, G1, G5, I2, X11	*Alnus, Ficus, Morus, Populus*	Cocquempot 2007, Cocquempot and Debreuil 2006, Dioli and Vigano 1990, Köhler 2000, Sama 2006b, Sama et al. 2010, Šefrová and Laštůvka 2005, Tomiczek and Hoyer-Tomiczek 2008, Wittenberg 2005

Table 8.1.2. List and characteristics of the Cerambycidae species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II).

Family species	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Arhopalus rusticus (Linnaeus, 1758)	phytophagous	Continental Europe	PT-AZO, PT-MAD	G3	*Pinus, Picea, Abies, Larix*	Fauvel 1897, Picard 1937, Serrano 1982
Aromia moschata (Linné, 1758)	phytophagous	Continental Europe	PT-AZO	I2	*Salix, Populus, Alnus*	Borges et al. 2005
Cerambyx carinatus Küster, 1846	phytophagous	Balkans	MT	G	*Prunus*	Sama and Cocquempot 1986
Cerambyx nodulosus Germar, 1817	phytophagous	Balkans	MT	G	*Pyrus, Malus*	Fauvel 1897, Schembri and Sama 1986
Clytus arietis (Linné, 1758)	phytophagous	Continental Europe	PT-MAD	E5, G, G1, G5	Deciduous trees (polyphagous)	Picard 1937, Wollaston 1854
Gracilia minuta (Fabricius, 1781)	phytophagous	Southern Europe	AT, CH, , ES-CAN, IE, LV, LT, PT-AZO, PT-MAD	F3, G, G5	Deciduous trees (polyphagous	Borges et al. 2005, Bytinski-Salz 1956, Lucht 1987, Speight 1988, Wollaston 1863
Icosium tomentosum atticum Ganglbauer, 1881	phytophagous	Southeastern Europe	FR	G3	Cupressaceae	Cocquempot et al. 2007, Pellegrin 1990
Monochamus galloprovincialis (Olivier, 1795)	phytophagous	Southwestern Europe	NL	G3	*Pinus*	De Fluiter 1950
Monochamus sartor (Fabricius, 1787)	phytophagous	Northern Europe, Alps	BE, , NL	G3	*Picea*	Fauvel 1884, Wiel 1956, Lucht 1987
Monochamus sutor (Linnaeus, 1758)	phytophagous	Central and Northern Europe	BE, PT	G3	*Picea, Pinus*	Speight 1988, Weyers 1876
Morimus asper funereus Mulsant, 1863	phytophagous	Southeastern Europe	CZ, MT	G	Deciduous trees (polyphagous	Schembri and Sama 1986, Šefrová and Laštůvka 2005

Family species	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Nathrius brevipennis (Mulsant, 1839)	phytophagous	Southwestern Europe	AT, BE, CH, CZ, DE, GB, IE, LU, LV, PL, PT-AZO	F3	Deciduous and conifer trees (polyphagous)	Adlbauer 2006, Borges et al. 2005, Duffy 1953a, Heyrovský 1930, Korcynski 1985, Lucht 1987, Sliwinski 1958, Speight 1988, Weidner 1973, Weyers 1875
Phymatodes testaceus (Linné, 1758)	phytophagous	Continental Europe	PT-AZO	G	Deciduous and fruit trees, preferably on *Quercus*	Fauvel 1897, Picard 1937, Wollaston 1854
Poecilium lividum (Rossi, 1794)	phytophagous	Southeastern Europe	BE, CH, CZ, DE, LU, NL	G,J1	*Quercus, Castanea*	Lucht 1987, Heyrovský and Sláma 1992, Horion 1974, Šefrová and Laštůvka 2005, Wittenberg 2005
Rhagium inquisitor (Linné, 1758)	phytophagous	Continental Europe	IE	G3	Conifers *(Pinus, Picea, Abies, Larix);* deciduous trees (*Betula, Fagus, Quercus*)	Speight 1988
Rosalia alpina (Linné, 1758)	phytophagous	Central Europe, Alps	MT	G, I2, J1	*Fagus*, and other deciduous trees	Horion 1974, Schembri and Sama 1986
Stictoleptura rubra (Linné, 1758)	phytophagous	Central Europe	PT-AZO	G3	Conifers (*Pinus, Picea, Abies, Larix*)	Borges et al. 2005
Stromatium unicolor (Olivier, 1795)	phytophagous	Southeastern Europe	PT-MAD	G	Deciduous trees (mostly) and conifers (polyphagous)	Fauvel 1897, Picard 1937
Trichoferus fasciculatus (Faldermann, 1837)	phytophagous	Southeastern Europe	CH, PT-MAD	G	Deciduous trees (polyphagous)	Allenspach 1973, Picard 1937
Trichoferus griseus (Fabricius, 1792)	phytophagous	Southeastern Europe	CZ	G	*Ficus, Pistacia, Rosa*	Šefrová and Laštůvka 2005
Xylotrechus arvicola (Olivier, 1795)	phytophagous	Southeastern Europe	SP-CAN	G	Deciduous trees (polyphagous)	Demelt 1974

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Weevils and Bark Beetles (Coleoptera, Curculionoidea) Chapter 8.2

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Abstract

We record 201 alien curculionoids established in Europe, of which 72 originate from outside Europe. Aliens *to* Europe belong to five families, but four-fifths of them are from the Curculionidae. Many families and subfamilies, including some species-rich ones, have few representatives among alien curculionoids, whereas some others are over-represented; these latter, Dryophthoridae, Cossoninae and specially Scolytinae, all contain many xylophagous species. The number of new records of alien species increases continuously, with an acceleration during the last decades. Aliens *to* Europe originate from all parts of the world, but mainly Asia; few alien curculionoids originate from Africa. Italy and France host the largest number of alien *to* Europe. The number of aliens per country decreases eastwards, but is mainly correlated with importations frequency and, secondarily, with climate. All alien curculionoids have been introduced accidentally via international shipping. Wood and seed borers are specially liable to human-mediated dispersal due to their protected habitat. Alien curculionoids mainly attack stems, and half of them are xylophagous. The majority of alien curculionoids live in human-modified habitats, but many species live in forests and other natural or semi-natural habitats. Several species are pests, among which grain feeders as *Sitophilus* spp. are the most damaging.

Keywords
Europe, Coleoptera, Curculionoidea, Curculionidae, alien species, invasive species, xylophagy, seed feeder

8.2.1. Introduction

The superfamily Curculionoidea encompasses the weevils and the bark and ambrosia beetles; here we will use „weevils" to refer to the entire superfamily. It is the most species-rich beetle clade, with more than 60,000 described species (Oberprieler et al. 2007). Four fifths of all weevils are in the family Curculionidae. Curculionoids are distributed worldwide, everywhere vegetation is found.

This is a rather homogeneous group, its members being generally easily recognizable despite various aspects. Adults are primarily characterized by the head being produced into a rostrum (snout) to which the antennae and mouthparts are attached. The rostrum is highly variable in size and shape, varying from as long as the body to very short or absent. Larvae, generally white and C-shaped, are catepillar-like (eruciform), soft-bodied, with legs being either vestigial or (usually) absent, except in some species of the primitive family Nemonychidae.

Except for a few rare species, adults and larvae of Curculionoidea are phytophagous. Larvae are mainly endophytic or subterranean. Weevils feed on a large variety of plants, attacking all parts. Many species are important pests for agriculture or forestry.

The Macaronesian islands[1] pose a special problem. While many of their weevils are only found on single islands or groups of islands and are thus clearly endemic, other species are shared between island groups, or between Macaronesian islands and the continental Europe or North Africa. For example, a number of scolytines specialized to *Euphorbia* are shared between the Canary Islands and Madeira, or between the Canary Islands and the Mediterranean and North Africa (Table 8.2.1). Given the difficulties involved with dispersal by these tiny insects over vast expanses of salt water, we have chosen to interpret the distributions of non-endemic species as resulting from recent human transport. We are well aware that rare instances of natural dispersal do occur, at least on evolutionary time scales: after all, such natural dispersal has resulted in many instances of well documented species radiations (Emerson 2008, Juan et al. 2000). Because of the inherent uncertainty in distinguishing between recent anthropogenic spread and older natural dispersal, we classify nonendemic species of these archipelagos as *presumed* aliens (they are indicated in tables 8.2.1 & 8.2.2). Without contradictory data, we consider: 1) species known from Europe and found on a Macaronesian island as *presumed* alien *in* Europe; 2) species known from Africa (and not from Europe) and found in Macaronesia as *presumed* alien *to* Europe; 3) species from the Canary Islands which also occur further north on Madeira or the Azores as *presumed* alien

[1] We include in our coverage the Macaronesian islands associated with European countries (Madeira, the Azores, the Canary Islands); we exclude the Cape Verde Islands.

from the Canary Islands and *presumed* alien *to* Europe. *Presumed* alien are often considered below separately than others, due to the uncertainty attached to their status and the geographical and biogeographical differences between Macaronesia and Europe.

We consider that 201 alien curculionoids currently live in Europe, of which 72 species originate outside of Europe (aliens *to* Europe, Table 8.2.1; 20 *presumed* alien are included) and 129 species originate from other parts of Europe (aliens *in* Europe, Table 8.2.2; 60 *presumed* alien are included)[2]. Except where otherwise noted, our discussion of exotic curculionoids only pertains to alien *to* Europe.

8.2.2. Taxonomy and biology

The systematics of the superfamily Curculionoidea have long been controversial, in part due to the enormous number of taxa involved, in part due to extensive parallel evolution arising from the similar ecologies of unrelated clades (Alonso-Zarazaga and Lyal 1999, Oberprieler et al. 2007). We follow here the current classification of Fauna Europaea (Alonso-Zarazaga 2004), which notably considers the traditional Platypodidae and Scolytidae families as subfamilies of Curculionidae.

About 5,000 native curculionoids live in Europe, distributed among 13 families. Comparatively, the alien entomofauna is very limited with only 72 established species recorded at this time (Fig. 8.2.1). These alien species belongs to five families, all of which have native representatives.

Anthribidae. Principally present in tropical areas, these largely fungus-feeding curculionoids generally live primarily in fungus-infested wood. There is only one alien species in Europe, *Araecerus coffeae*, which is a seed feeder, an exceptional biology in this family.

Apionidae. Characterized in part by their non-geniculate antennae and endophytous larvae, these tiny curculionoids are represented in Europe by three alien species, all living on alien ornamental *Alcea* (Malvaceae).

Dryophthoridae. This family contains large weevils mainly living on woody monocotyledons. Alien dryophthorids consist of woody monocotyledons borers and seed feeders. They are particularly numerous compared with the world fauna (Fig. 8.2.1) and especially with respect to the few native species in Europe (8 aliens vs 6 natives, according to Fauna Europaea (Alonso-Zarazaga 2004)). This situation could be explained first by the few woody monocotyledons in Europe-native flora in contrast with the several woody monocotyledons introduced in Europe for ornamental or agricultural purpose. The human-mediated transport of seeds, and consequently seed feeders, is probably a further explanation.

2 Other aliens have been recorded, but have not been taken into account here because their establishment have not been confirmed. We have also excluded some possible *presumed* aliens due to the uncertainty about their distribution.

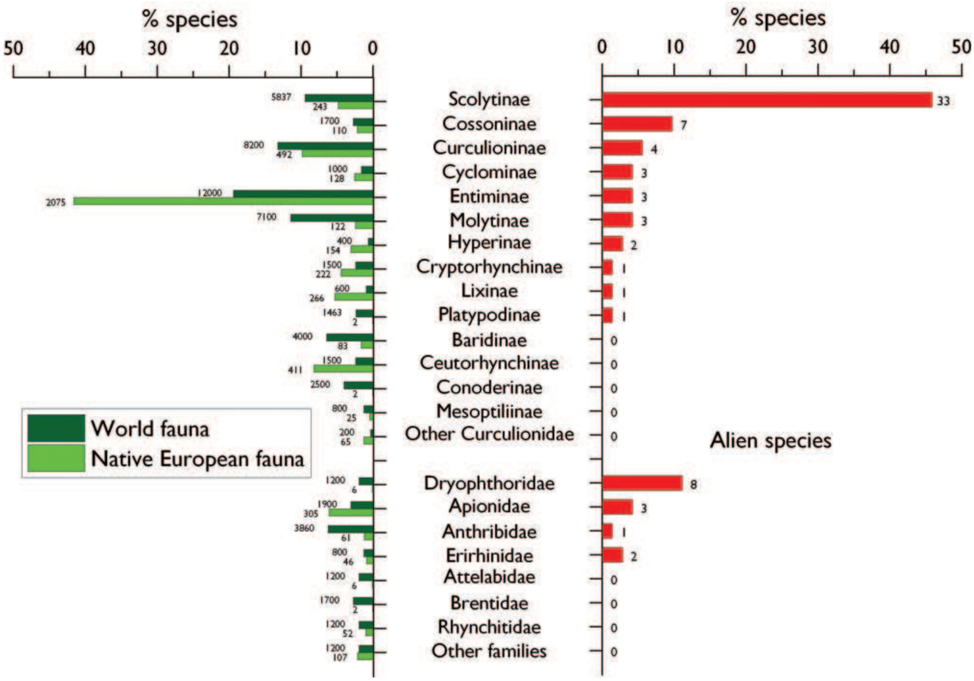

Figure 8.2.1. Taxonomic overview of Curculionoidea species alien to Europe compared to the native European fauna and to the world fauna. **Right**- Relative importance of the Curculionoidae families and subfamilies in the alien entomofauna is expressed as percentage of species in the family/ subfamily compared to the total number of alien Curculionidea in Europe. Subfamilies of Curculionidae and other families of Curculionidea are presented in a decreasing order based on the number of alien species. The number over each bar indicates the total number of alien species observed per family/ subfamily. **Left**- Relative importance of each family/ subfamily in the native European fauna of Curculionidea and in the world fauna expressed as percentage of species in the family/ subfamily compared to the total number of Curculionidea in the corresponding area. The number over each bar indicates the total number of species observed per family/ subfamily in Europe and in the world, respectively

Erirhinidae. Curculionoids of this small family mainly live on herbaceous monocotyledons, often aquatic ones. With two alien species, they are relatively well represented in Europe.

Curculionidae. This huge family encompasses more than 80% of weevils and notably includes the bark beetles and pinhole borers (Scolytinae and Platypodinae). Curculionids have a large variety of habits, but are all phytophagous. The European species are distributed in 16 subfamilies. The alien species belong to 10 subfamilies, all having native representatives. Many subfamilies, including the world's largest (Entiminae, Curculioninae and Molytinae), are under-represented among alien curculionoids compared with their world importance in the superfamily (Fig. 8.2.1). On the other hand, the subfamily Cossoninae, which mainly contains wood-boring weevils, are over-represented, but the most remarkable result is the over-representation of Scolytinae.

Scolytinae are small, cylindrical wood borers, without a rostrum or with only a very reduced one; they include some of the most important forest pests in the world. The majority are phloeophagous, breeding in the inner bark. Most others are xylomycetophagous, feeding on symbiotic fungi which they cultivate in tunnels in the wood (ambrosia beetles). The scolytines represent about 10% of world curculionoids but almost half of curculionoids alien *to* Europe. Alien bark beetles represent more than 12% of all bark beetle species in Europe. The over-representation of Scolytinae is related to the frequency with which they are transported in wooden packing material, pallets, and timber (Haack 2001, 2006, Brockerhoff et al. 2006). All stages of these beetles can survive long voyages well, since both adults and larvae are in tunnels under bark or in wood and not directly exposed to temperature extremes or dessication. The importance of a stable, protected microenvironment is illustrated by the high prevalence of ambrosia beetles in the Scolytinae plus Platypodinae (35%) among successful aliens *to* Europe (Table 8.2.1), compared with the prevalence of ambrosia beetles in these groups in temperate climates generally (below 20%: Kirkendall 1993). The establishment of ambrosia beetles in Europe is further facilitated by polyphagy (11/12 spp.) and inbreeding (10/12 spp.), as is generally believed to be the case for ambrosia beetles globally (Kirkendall 1993, Haack 2001).

The curculionoids alien *in* Europe are more representatives of Europe-native fauna. Scolytines (25% of aliens *in* Europe) are also over-represented compared with their importance among European curculionoids (5%), but not cossonines (3% of aliens *in* Europe). On the other hand, Entiminae (26% of alien *in* Europe, mostly *Otiorhynchus* and *Sitona*) are under-represented compared with the European fauna, but less so than among aliens *to* Europe.

8.2.3. Temporal trends

Of the five families considered in this chapter, the first information concerning an alien species in Europe was probably the description by Ratzeburg in 1837 of *Xyleborus pfeilii* based on specimens from southern Germany[8]. The curculionid *Pentarthrum huttoni* was introduced to Great Britain from New Zealand in 1854, and has subsequently become naturalized in many European countries (Table 8.2.1). Only three other introduced species were recorded in the second half of 19th century.

With the beginning of the 20th century, alien species began to be discovered more frequently, though this was limited to sporadic introductions (about 2 species per decade) confined to southern Europe – which perhaps provided more favourable climatic conditions – and along the main routes of international trade. Since the 1920s the rate of new introductions has slightly increased (Fig. 8.2.2), with a mean of nearly three species every decade, but remaining stable until middle of 1970s.

Despite the European laws regulating the trade of plant material, the number of records of new exotic species introduced to Europe has increased rapidly since 1975 and especially since 2000, reaching worrying levels with an average of more than one

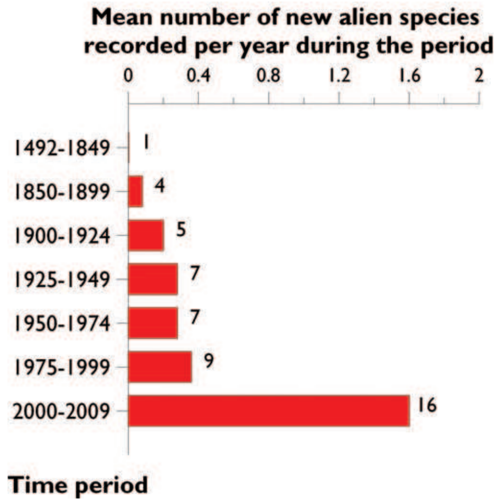

Figure 8.2.2. Temporal trend in establishment of Curculionoidea species alien *to* Europe from 1492 to 2010. *Presumed* alien species are excluded. The number besides each bar indicates the absolute number of new records during the time period. For the introduction year of each species see Table 8.2.1.

species per year (16 new species from 2000 to 2009: Table 8.2.1), and a peak of five new species per year in 2004 (8 species in 2003–2004). It is too early to say if the relatively low number of establishments observed since 2005 will be confirmed or is only due to stochastic variations. However, if the trend towards increasing rates of introduction continues unabated, in a few decades the mean number of alien species becoming established in Europe could reach several per year.

The temporal trend of alien curculionoids establishment is very similar to that observed in Europe for all alien terrestrial invertebrates (Roques et al. 2009, but see also Smith et al. 2007 for contradictory (more limited) data). On the other hand, this trend varies among weevils. Aliens from Asia follow the general trend (half of them have been recorded after 1975, a third after 2000), but the increasing of establishment rate is faster for those from North and South America (two-thirds of them have been recorded after 2000) while it is slower for those from others continents (half of them have been recorded before 1950, and none after 2000). Regarding feeding habits, all aliens follow the general trend except those with spermatophagous larvae, which show no trend. This particularity of the formers seems related to the oldness and intensity of human-mediated seed transport.

Unfortunately, for many alien species spread over large parts of Europe, data on the place and time of introduction are lacking, and generally the data on time of arrival of exotic species are very weak. Often, introduced species – especially those which are not pests – are first noticed only many years after arrival, or following subsequent and repeated introductions. As prompt communication of new findings is extremely important for the application of specific monitoring and eradication programs, the poor quality of these data is a major obstacle to aliens management.

8.2.4. Biogeographic patterns

Origin of alien species

All *presumed* aliens probably come from Africa (among which 35% from the subregion Macaronesia). These species are not included in further discussion due to uncertainty of their status and specially because their arrival modes have probably been different from other aliens due to proximity of the source region.

A probable region of origin could be specified for 51 of the 52 curculionoid species alien *to* Europe. There is one species, *Sitophilus zeamais* (Dryophthoridae), whose region of origin is uncertain (*cryptogenic*). *Cryptogenic* species are thus rare in this group compared to all alien terrestrial invertebrates (14%: Roques et al. 2009). *Sitophilus zeamais* is associated with maize crops, *Zea mays*, and feeds on maize grain stores, and it is likely that this species is American.

More than one-third (40%) of the exotic curculionoid species originate from Asia. Central and South America represents the second most important region of origin, with 19% of the species coming from this area. North America and Australasia both represent 14% of the contributing regions. Africa is a minor region of origin (6%), and the remaining species (6%) arrived from tropical or subtropical areas but the region of origin could not be precisely identified (Figure 8.2.3). This distribution is rather similar to that for all alien terrestrial invertebrates (Roques et al. 2009). The main differences are the under-representation of African aliens (6% vs. 12%) and the over-representation of South American (19% vs. 11%) and Australasian (14% vs. 7%) ones. A rather surprising result is that species originated from areas with tropical or subtropical climates all around the world represent about half of alien curculionoids.

Thirteen out of the twenty-one alien species originating from Asia are from the family Curculionidae, twelve species belonging to the subfamily Scolytinae and one species to the subfamily Cyclominae. Other families consist of Dryophthoridae (4 spp.), Apionidae (3 spp.) and Anthribidae (1 sp.). Scolytines originate from very different parts of this large continent. For example *Cyclorhipidion bodoanus* is native to Siberia and temperate northeast Asia, *Phloeosinus rudis* to Japan, and the three species of the genus *Xylosandrus* to Southeast Asia. In contrast, all the weevils of the Dryophthoridae family originate from tropical Asia. This group includes the banana root weevil *Cosmopolites sordidus*, the coconut weevil *Diocalandra frumenti*, the palm weevil *Rhynchophorus ferrugineus* and the rice weevil *Sitophilus oryzae*. The introduced apionids, *Alocentron curvirostre*, *Aspidapion validum* and *Rhopalapion longirostre*, all feed on flowers and seeds of *Alcea rosea* and other Malvaceae species (Bolu and Legalov 2008); these all originate from central Asia. Finally, the anthribid *Araecerus coffeae* originates from India.

The ten curculionoid species coming from Central and South America consist of curculionids (8 spp.) and dryophthorids (2 spp.). Curculionids originating from this region are as highly diverse taxonomically (they are distributed in six subfamilies) as in feeding habits. The native ranges of many species largely extend through the continent

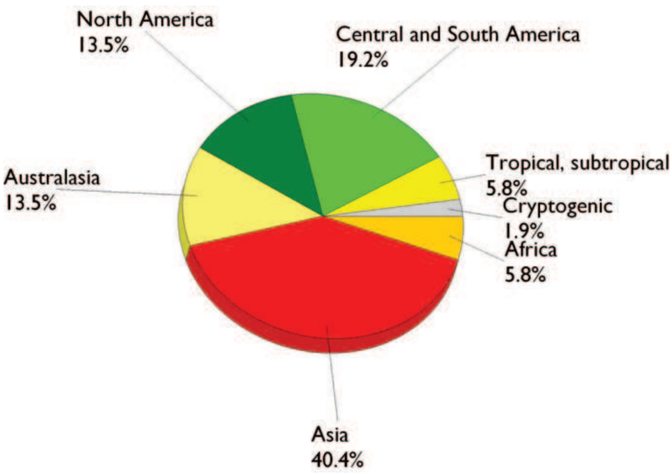

Figure 8.2.3. Origin of Curculionoidea species alien *to* Europe. *Presumed* alien species are excluded.

(including sometimes part of North America), though those of others are more narrow as for *Rhyephenes humeralis* (central Chile and neighboughring area of Argentina) and *Paradiaphorus crenatus* (Brazil).

Seven alien curculionoids are known to originate from North America. They include five species of the family Curculionidae and two of Erirhinidae. Many curculionids introduced from North America are xylophagous *sensu lato*[7], feeding on several broad-leaved or coniferous hosts. The exceptions are the ash seed weevil *Lignyodes bischoffi* and *Caulophilus oryzae*, originally from the southeastern USA, which feeds on seeds. In contrast, the two Erirhinidae species feed externally on weed roots and ferns, respectively.

Seven curculionoid species come from Australasia, all curculionids: four cossonines, two molytines and one cyclomine. Three woodboring weevils (*Pentarthrum huttoni*, *Euophryum confine* and *E. rufum*, all from Cossoninae), feeding on decaying wood, originate from New Zealand. The four other species were unintentionally introduced from Australia. All feed inside plant material (*xylophagous* or *herbiphagous*), except the Eucalyptus snout beetle, *Gonipterus scutellatus*, a defoliator of *Eucalyptus* trees originated from Southern Australia.

Only three curculionoid species are known to originate from Africa, a curculionine and two scolytines. The palm flower weevil, *Neoderelomus piriformis*, probably originates from North Africa; it feeds on but also pollinates flowers of palms like *Phoenix canariensis*. The scolytines both originate from Canary Islands; *Dactylotrypes longicollis* breeds in *Phoenix canariensis* seeds, while *Liparthrum mandibulare* is a highly polyphagous phloeophage.

Three cosmopolitan curculionoid species originate from undetermined areas of the tropical and subtropical parts of the world: the tamarind seed borer, *Sitophilus linearis* (Dryophthoridae), and the palm seed borers *Coccotrypes carpophagus* and *C. dactyliperda* (Scolytinae). As seed-feeders, they are readily distributed through commerce, which probably explain the uncertainty about their origin.

Concerning the curculionoids alien *in* Europe, nine-tens of these (114 spp. among 129, Table 8.2.2) are introduced from mainland Europe to islands (mainly the Canary Islands, the Azores, the British Isles and Madeira). They are often widespread continental species which have been introduced to islands by human transport. Other cases are mainly species of southern and western regions which were introduced into northern Europe (as *Otiorhynchus corruptor*), especially to Denmark and Sweden. However, some species have moved westwards (as *Otiorhynchus pinastri* and *Phloeotribus caucasicus*) and even southwards (*Ips duplicatus*).

Distribution of alien species in Europe

As for the other arthropod groups, alien curculionoid species are unevenly distributed throughout Europe, which may partly reflect differences in sampling intensity (Fig. 8.2.4, Table 8.2.1). In continental Europe, mainland Italy and France host the largest number of species alien *to* Europe, with 28 and 26 introduced curculionoid species, respectively. These countries are followed by continental Spain (17 spp.), Austria (15 spp.), and Germany, Switzerland and United Kingdom[3] (13 spp.). This distribution is similar as that of all alien terrestrial invertebrates (Roques et al. 2009). The number of aliens per country significantly decreases eastwards (y=12 - 0.29*longitude, R^2=0.21, $F_{1,31}$=8.08, p=0.008), but it is mainly correlated with human variables, country population (y=-1.5 + 3.7ln(population), population in million inhabitants, R^2=0.39, $F_{1,31}$=19.6, p=$1*10^{-4}$) and country importation values (y=-32 + 3.5ln(value), value 2003–2007 in million USD: The World Factbook 2009, R^2=0.53, $F_{1,29}$=32.4, p=$4*10^{-6}$)[4]. The best model integrates importations and latitude (y=-19 + 3.6ln(value) - 0.28*latitude, value in million USD, R^2=0.60, $F_{2,28}$=20.6, p=$3*10^{-6}$), indicating that alien establishment is favored by human trade and warm climate. The abundance of aliens in mainland Italy and France is not fully explained by the model (predicted values 17 and 16 alien species, respectively); it is likely related to a combination of the diversity of habitats and plants present with the favorable climate and the importance in international shipping.

Islands have a rather rich alien curculionoid fauna, especially Macaronesia: 29 (of which 14 *presumed*), 18 (8 *presumed*) and 10 (2 *presumed*) species in the Canary Islands, Madeira and the Azores, respectively. These islands are followed by Sicily (10 spp.), Corsica (8 spp.) and Malta (6 spp.). As it has been found for other alien terrestrial invertebrates (Roques et al. 2009), the number of alien curculionoids per km^2 in European islands is higher than in continental countries (on average 2.8 vs 0.17

[3] Concerning species alien *to* Europe, United Kingdom characteristics are closer to those of continental countries than to those of other islands, so we consider it as part of continental Europe. This is likely related to its large size and population.

[4] Computations were performed without small countries where no alien curculionoid is recorded, because this absence is probably due to lack of data. Israel was also excluded due to its special location.

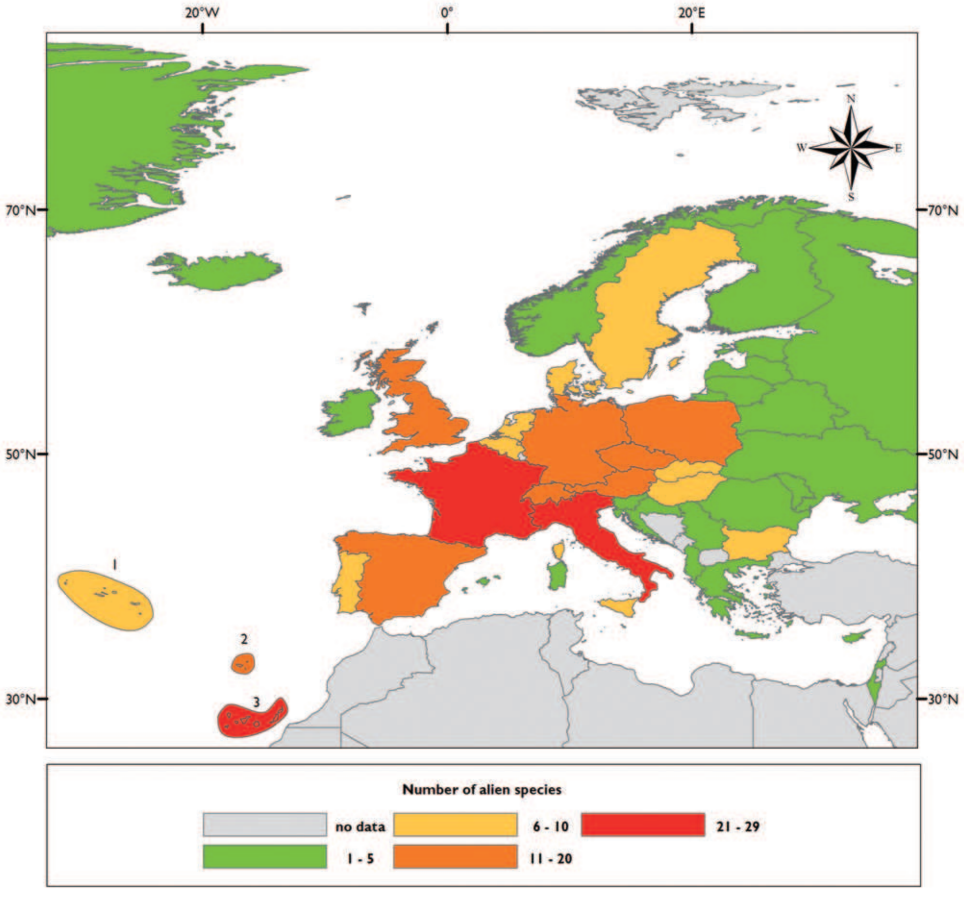

Figure 8.2.4. Comparative colonization of continental European countries and islands by Curculionoidea species alien *to* Europe. Archipelagos: **1** the Azores **2** Madeira **3** the Canary Islands.

alien/1000km^2, R^2=0.10, $F_{1,58}$=6.56, p=0.013). Aliens density is specially high in Madeira and Malta (23 and 19 alien/1000km^2, respectively), perhaps because these tiny islands are stopping places on trade routes. Islands show no global trend of alien distribution. However, cold nordic islands (Greenland, Iceland, Svalbard) host few aliens, and in Macaronesia alien number (specially *presumed* alien number) decreases when distance to continent increases.

Near half of alien curculionoid species (33 spp.) have been observed in only one country, most of them (31 spp.) in a peninsular region or on islands: Italy, Iberia, Macaronesian islands, Malta or the British Isles. Aliens introduced to such areas are less likely to move to nearby countries in comparison with aliens in other mainland regions, but Austria and Russia also host each an own alien species. As examples, *Syagrius intrudens* from Australia is encountered only in Great Britain, *Naupactus leucoloma*, from South America, is found only in the Azores, and *Paradiaphorus crenatus*, from Brazil, is known only from the Canary Islands. After the Canary Islands, Italy hosts the highest number of alien species unique to one country, eight in total, of which six are from subfamilies Scolytinae and Platypodinae. Also, the recent arrival of these species, most of them having first been discovered later than 2000, may in part explain their currently restricted distribution.

Ten alien species (14%) are limited to two countries. In almost all cases, the species are found in neighbour countries, as with the scolytine *Dryocoetes himalayensis* in France and Switzerland, and *Macrorhyncolus littoralis* in Great Britain and Ireland. One alien species, *Scyphophorus acupunctatus*, occurs in two distinct regions, Sicily and France, suggesting the possiblity of multiple introductions (this suggestion is supported by the previous interceptions of this species in different european countries: EPPO 2008).

At the other extreme, the rice weevil *Sitophilus oryzae* has been found in 34 European countries, and two other seed feeders, *Sitophilus zeamais* and *Rhopalapion longirostre*, occur in 23 and 21 countries. Their feeding habits in association with frequently transported seeds or stored products presumably explain this broad distribution. Another eleven species are found in 10 or more countries. These include several long-established species: *Xyleborus pfeilii*[8], the wood-borer *Pentarthrum huttoni*, the palm seed borer *Coccotrypes dactyliperda* and the parthenogenetic weevil *Asynonychus godmani*. However, the relatively recently introduced (1993) palm weevil *Rhynchophorus ferrugineus* is also widely distributed, occurring in most of the Mediterranean region, which attests their high dispersal capabilities (natural and human-mediated). Overall, alien weevil species are more widespread in Europe than other alien terrestrial invertebrates, with 40% of species distributed in more than two countries vs. only 22% (Roques et al. 2009).

8.2.5. Main pathways and factors contributing to successful invasions

There are two components to successful invasion, dispersal and establishment. Dispersal to new continents by phytophagous arthropods is now almost entirely due to human transport, the magnitude of which has inceased exponentially in recent decades. Plant feeding arthropods are carried in and on live plants and fruits, in wood, and as stowaways in shipments and baggage. Deliberate introductions of arthropods are less frequent, and most involve exotic organisms imported for biological control. Establishment of new arrivals depends on availability of appropriate habitats near sites of introduction, ability to compete with similar species already present, and on a reasonable tolerance for the local climate.

All exotic species of Curculionoidea have been introduced accidentally in Europe, vs. only 90% for all alien terrestrial invertebrates (Roques et al. 2009). The lack of intentional introductions of weevils could be related to their poor potential for biological control. One exotic weevil species (*Stenopelmus rufinasus*) has been used successfully for biological control of the American water fern *Azolla filicoides* in South Africa and to a less extent in the British Isles, but its first introduction in Europe was accidental (Sheppard et al. 2006, Baars and Caffery 2008).

As is the case for other regions in the world, many of Europe's alien curculionoids have presumably arrived via the shipping of wooden materials: pallets, crating, and barked or unbarked timber (Brockerhoff et al. 2006, Haack 2001, 2006). Bark and wood boring species make up half of all alien weevils (50%); these have almost certainly been introduced with wood transport and solid wood packaging materials. Logs with bark are ideal for transporting bark beetles and other weevils. However, even debarked logs can contain live wood borers such as ambrosia beetles. Although some wood-boring beetles have more restrictive requirements (e.g. high humidity and decayed wood: *Euophryum confine*, *E. rufum*, *Pentarthrum huttoni*), even these can often survive a few days or even weeks of transport. The east Asian ambrosia beetle *X. germanus* provides a typical example for entry by wood-borers. It was introduced to the USA (1932), where it was discovered in imported wine stocks in greenhouses; the species spread rapidly and has become an important nursery pest in warmer parts of eastern North America (Ranger et al. 2010). In Europe, it was first recorded after World War II, in Germany, where the species probably had been introduced with wood imported from Japan to southern Germany early in the 20th century; the present distribution area includes twelve European countries (Table 8.2.1).

Seed feeders (20%) are introduced with the seeds, which are also an excellent way for transporting insects. Several of these species are associated with agricultural products (e.g. *Caulophilus oryzae*, *Sitophilus oryzae* and *S. zeamais*), however most species feed on ornamental or forest seeds (e.g. *Rhopalapion longirostre* on *Alcea*, *Lignyodes bischoffi* on ash seeds, *Dactylotrypes longicollis* on palm seeds).

Other alien species (30%) live on or inside leaves and nonwoody stems, or in the soil. The formers can be introduced with their host plants or with host plant products (e.g. *Gonipterus scutellatus* with eucalyptus, *Listroderes costirostris* with plants such as tobacco); weevils living around roots (e.g. *Asynonychus godmani*) are transported with living plants. These feeding habits (plus root boring, which doesn't exist among aliens *to* Europe) are more frequent among *presumed* aliens *to* Europe and among aliens *in* Europe (52%); both cases result from a rather short distance transport, which likely allows survival of less protected insects (among wood boring scolytines, *phloeophagous* species are similarly much more frequent than *xylomycetophagous* species among *presumed* aliens *to* Europe and among aliens *in* Europe, contrary to what is observed among other aliens *to* Europe).

Currently, most introductions are due to international trade, but the increasing movement of fruits and plants by travelers, which is much more difficult to check, may contribute to the future diffusion of new alien species.

Newly arrived phytophages must find suitable hosts. The likelihood of success is greatly enhanced if the species is not too host specific, or if its preferred hosts are abundant. Not surprisingly, the majority of established exotic weevils in Europe are polyphagous, and the hosts of others are often widespread and abundant plants (Table 8.2.1).

Parthenogenesis and inbreeding further increase the chances for successful colonization. When an exotic species is first introduced to a new area, it faces a variety of problems associated with low density which reduce the likelihood of successful establishment and slow the rate of invasion (Tobin et al. 2007, Liebhold and Tobin 2008, Contarini et al. 2009). New populations create problems for mate finding; parthenogenetic females do not mate, and inbreeding females mate with brothers while in the natal nest, before dispersal (Jordal et al. 2001); in both cases, there is no problem of mate location and new populations can be established by single females. Very small populations (such as those in recent colonizations) may suffer from high levels of inbreeding depression (Charlesworth and Charlesworth 1987); however, regular inbreeding species such as the invasive scolytines have presumably purged their genomes of the deleterious alleles responsible for inbreeding depression (Charlesworth and Charlesworth 1987, Jordal et al. 2001, Peer and Taborsky 2005). Only a few invasive curculionoid species are parthenogenetic: *Asynonychus godmani*, *Lissorhoptrus oryzophilus*, *Listroderes costirostris* (Morrone 1993) and *Naupactus leucoloma*, whose males are unknown outside its native range (Lanteri and Marvaldi 1995). However, over half of the alien scolytines inbreed (59%, *presumed* aliens excluded), compared with less than a third of scolytines native to Europe and about a fourth of Scolytinae species worldwide (Kirkendall 1993).

8.2.6. Most invaded ecosystems and habitats

All alien curculionoid species are phytophagous, as are nearly all curculionoids worldwide. Most of the species have a cryptic way of life, at least during larval stage, feeding inside plant tissues such as stems or seeds, or living in the soil; only 9% are *leaf/stem browsers*. Stems and trunks is the major feeding niche of most alien curculionoids (65%). Most of these are bark beetles, ambrosia beetles or other wood borers (50%); *herbiphagous* (15%) comprise the remaining. Seeds are the second most important feeding niche (18%), followed by leaves (9%; some species could also attack non woody stems) and roots (6%). Last species, *Neoderelomus piriformis*, feeds on flowers, and acts as pollinator in palm trees.

By contrast, of the curculionoids alien in Europe, only 33% are wood borers, among which most are *phloeophagous* (28%). A third (30%) attack roots, especially *root browsers* as *Otiorhynchus* and *Sitona* (26%), the remaining (4%) being *root borers*. *Herbiphagous* (18%), *spermatophagous* (15%) and *leaf/stem browsers* (4%) comprise the remaining.

Near half of the alien curculionoid species established in Europe colonize urban and peri-urban habitats, primarily parks and gardens (27%) and around buildings (11%). Woodlands is also a frequent habitat for the alien curculionoids (27%), beyond natural heathlands (16%), cultivated agricultural lands (9%) and greenhouses (5%). Only three species occur in wetland habitats, one in coastal and two in inland surface water (Fig. 8.2.5). The importance of natural heathlands is in fact mainly limited to specific areas, most of the species recorded in these habitats being *presumed* aliens attacking euphorbias in Macaronesian xerophytic heathlands.

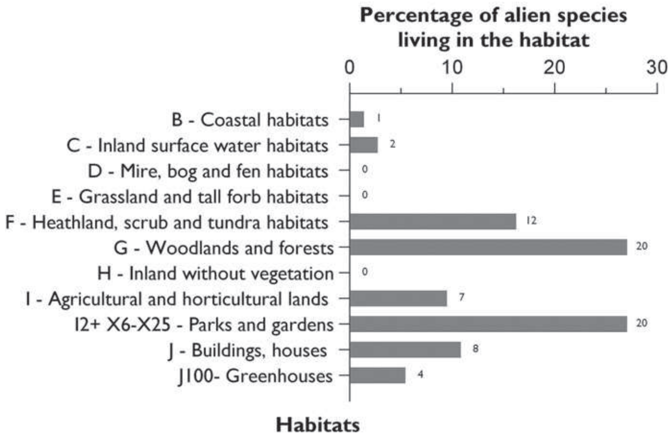

Figure 8.2.5. Main European habitats colonized by Curculionoidea species alien *to* Europe. The number besides each bar indicates the absolute number of alien curculionoids recorded per habitat. Note that a species may have colonized several habitats.

This pattern differs from the average value observed for all arthropods, where only a fourth of the species is recorded in natural or semi-natural habitats, and where agricultural lands and greenhouses contain more alien species than woodlands. That could be obviously related to the high frequency of xylophagous *sensu lato*[7] habits in alien curculionoids. Both deciduous trees, such as *Populus* sp. and *Fraxinus* sp, and conifers in the genera *Picea* and *Pinus* are colonized by several alien curculionoid species utilizing trees. *Eucalyptus* plantations are also affected by a defoliating curculionid, *Gonipterus scutellatus*, both host and weevil originating in Australia. In urban and suburban areas such as gardens and parks, other trees species, mainly exotics and in particular palm trees, are also affected by alien curculionoids.

8.2.7. Ecological and economic impact

Ecological impacts of alien insects are poorly known in general (Kenis et al. 2009), and the impacts of Curculionoidea species alien *to* Europe seem not to have been documented at all.

Their economic impact is better known, reflecting the economic importance of many of these alien species. A third of the Curculionoidea species alien *to* Europe (26 species) have a known economic impact, a much higher proportion than for native weevils, even though the latter contain numerous pests. Nevertheless, this high proportion may partly be an artefact, since pests have a higher probability of being detected.

The most damaging species are the four attacking stored products. The rice weevil *Sitophilus oryzae* and the maize weevil *S. zeamais* are among the main pests of stored grains worldwide, destroying significant amounts and incurring high pest management

Figure 8.2.6. Examples of alien curculionoids: *Gonipterus scutellatus.* Adult damage on *Eucalytus sp*. (Credit: Alain Roques).

costs[5] (Balachowsky 1963, Pimentel 1991). Larvae develop in cereal seeds and adults feed on these seeds as well as on a wide variety of stored products, products derived from cereal grains and even dried vegetables. Damages is exacerbated by incompletely dried stored products (Balachowsky 1963). In addition to their direct damage, these species facilitate attacks of grains by other pests. *Caulophilus oryzae*, a less widespread species, sporadically causes the same kind of damages, while *Araecerus coffeae* attacks grains but mainly less common products such as stored coffee and cocoa beans.

Five species attack native or introduced cultivated plants. *Listroderes costirostris* attacks a wide range of vegetables and weeds; adults can also damage foliage of fruit trees. The recently established whitefringed weevil, *Naupactus leucoloma*, is also highly polyphagous; its soil-inhabiting larvae are a serious pest of many agricultural crops. The banana root weevil, *Cosmopolites sordidus*, and *Paradiaphorus crenatus* are important pests of tropical cultures (banana and pineapple, respectively). Their economic impact is currently limited in Europe due to the limited distribution of their hosts in this area and a rather low aggressiveness in its climate, but it could increase later in the future according to the global warming. The last species is the rice water weevil, *Lissorhoptrus oryzophilus*. Recently introduced in Europe, it is a major pest of rice, but also attacks indigenous *Carex*.

Eight species damage different ornamental plants and trees, mainly introduced tropical or subtropical species. The palm weevil *Rhynchophorus ferrugineus* is a dangerous pest of palms which has rapidly colonized the Mediterannean basin. On the Canary Islands, palms are also attacked by the lesser coconut weevil *Diocalandra frumenti*. Even if damage are mainly esthetic, they are worrying because this insect princi-

[5] Damages are also due to the grain weevil *S. granarius*, probably alien too, but not taken into account here because it has been established in Europe at least since Antiquity.

Figure 8.2.7. Examples of alien curculionoids: *Rhynchophorus ferrugineus*. Female, larvae and damage (Credit: Juan Antonio Ávalos, Universidad Politécnica de Valencia).

pally attacks *Phoenix canariensis*, an endemic palm which is emblematic of the Canary Islands where it is widely used for landscaping and is a major element of coastal landscape. *Asynonychus godmani* attacks roots of a large variety of ornamental shrubs and fruit trees, native or introduced. Others species are monophagous or oligophagous on introduced hosts: the tamarind seed borer *Sitophilus linearis* on *Tamarindus indica*, *Demyrsus meleoides* on cycadophyts, *Scyphophorus acupunctatus* on Agavaceae species, *Phloeotribus liminaris* on *Prunus serotina*, *Phloeosinus rudis* on Cupressaceae species.

Five species have an impact on forests or related habitats. Three attack live exotic or native trees. The Eucalyptus snout beetle *Gonipterus scutellatus* is an important pest of *Eucalyptus* everywhere it has been introduced (see factsheet 14.12). This defoliator causes severe damage and wood loss, particularly on *E. globulus*, the major cultivated *Eucalyptus* species in southern Europe. *Rhyephenes humeralis* attack another introduced tree, *Pinus radiata*, but causes less damage. *Megaplatypus mutatus* is one of the few platypodine beetles which breeds in live trees; it is highly polyphagous, but in Europe it has thus far only been found to damage *Populus* plantations in Italy (Alfaro et al. 2007). The two other species depreciate wood stock. *Gnathotrichus materiarius* is a common pest of a large variety of conifer wood, and *Xylosandrus germanus* sporadically attacks mainly broadleaf wood.

Pentarthrum huttoni and the two *Euophryum* species live in rotting wood, so their economic impact is generally low, though they do attack wood of historically signifi-

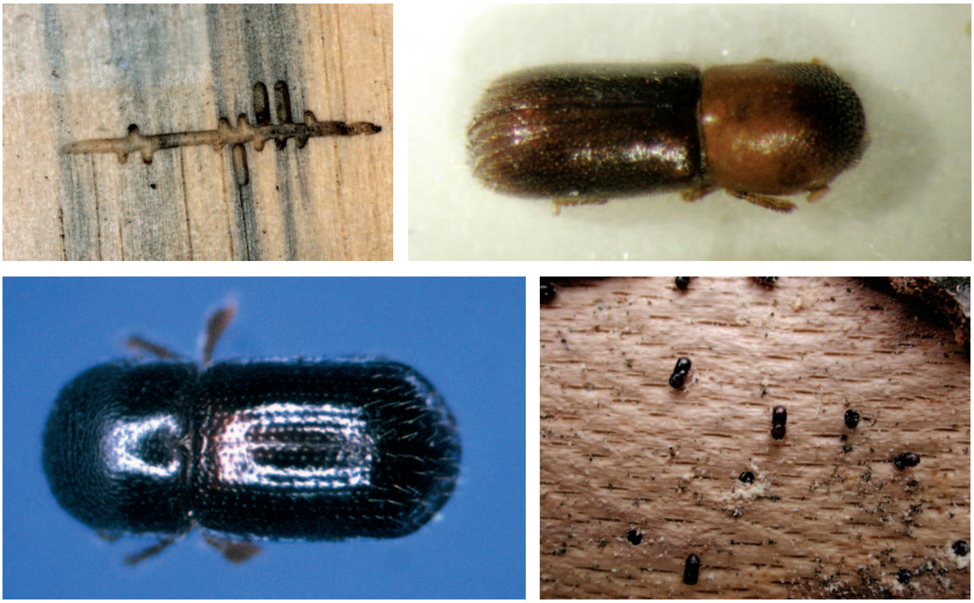

Figure 8.2.8. Examples of alien curculionoids: Scolytinae. Top left: *Gnathotrichus materiarius*: gallery in wood (Credit: Louis-Michel Nageleisen). Top right: *Cyclorhipidion bodoanus*: femelle (Credit: Louis-Michel Nageleisen). Bottom: *Xylosandrus germanus* (Blandford 1894): female (Credit: Daniel Adam), adults and gallery holes on wood (Credit: Louis-Michel Nageleisen).

cant artefacts or buildings. Finally, as opposed to all previous species, the introduced frond-feeding weevil *Stenopelmus rufinasus* has a positive impact due to its hability to control the invasive red water fern *Azolla filiculoides*.

8.2.8. Conclusion

The superfamily Curculionoidea is well represented among alien species now established in Europe. Alien weevils show specific characteristics comparing both native and world ones, which seem result from a selection of species having high capabilities to human-mediated dispersal and establishment in a new habitat. Thus, they have often cryptic habits, as seed boring or wood and plant boring, leading to over-representation of bark and ambrosia beetles and other xylophagous *sensu lato*[7] species; alien weevils are consequently more numerous in natural areas than other terrestrial invertebrate aliens. Seed feeders are the major alien pests. Alien species are mainly originated from Asia, which is related to the importance of trade with this continent, and many of them come from different tropical or subtropical areas.

The more worrying observation is the fast increase in the invasion rate during last decades, as noticed for all terrestrial invertebrate aliens. Without appropriate control, the invasive pressure will probably continue to increase in the future, further threatening European people and ecosystems, more especially as global warming may allow the naturalization of more tropical and subtropical species accidentally introduced into Europe and particularly the Mediterranean.

References

Abbazzi P, Osella G (1992) Elenco sistematico-faunistico degli Anthribidae, Rhinomaceridae, Attelabidae, Apionidae, Brentidae, Curculionidae Italiani (Insecta, Coleoptera, Curculionoidea): I Parte. *Redia* 75: 267–414.

Abbazzi P, Colonnelli E, Masutti L, Osella G (1994) Coleoptera Polyphaga XVI (Curculionoidea). In: Minelli A, Ruffo S, La Posta S (Eds) *Checklist delle specie della fauna italiana 61*. Bologna: Calderini, 35–64.

Alexander KNA (2002) The invertebrates of living & decaying timber in Britain and Ireland - a provisional annotated checklist. English Nature Research Reports 467. 142 pp.

Alfaro RI, Humble LM, Gonzalez P, Villaverde R, Allegro G (2007) The threat of the ambrosia beetle *Megaplatypus mutatus* (Chapuis) (=*Platypus mutatus* Chapuis) to world poplar resources. *Forestry* 80: 471–479.

Alonso-Zarazaga MA (Ed) (2004) Fauna Europaea: Coleoptera 1, Curculionoidea. Fauna Europaea version 1.1. http://www.faunaeur.org/.

Alonso-Zarazaga MA, Goldarazena A (2005) Presence in the Basque Country of *Rhyephenes humeralis* (Coleoptera, Curculionidae), a pest of *Pinus radiata* coming from Chile. *Boletin de la S.E.A.* 36: 143–146.

Alonso-Zarazaga MA, Lyal CHC (1999) A World Catalogue of Families and Genera of Curculionoidea (Insecta: Coleoptera) (excepting Scolytidae and Platypodidae). Barcelona: Entomopraxis S. C. P. 315 pp.

Angelov P (1960) Prouchvaniya vurkhu entomofaunata na parka Otdich I kultura (mestnostta Ostrova) kray Plovdiv s nyakoi faunistichni belezki. *Godishnik na muzeite v Plovdiv* 3: 7–40.

Arzone A (1976) Un nemico dell'Eucalipto nuovo per l'Italia. *Apicoltore Moderno* 67: 173–177.

Audisio P, Cornacchia P, Fattorini L, Franceschi S, Gatti E et al. (2008) Selected beetle families in natural forests and Norway spruce stands at Vincheto di Celarda Nature Reserve and the effects of conservation actions (Coleoptera). In: Hardersen S, Mason F, Viola F, Campedel D, Lasen C et al. (Eds) Research on the natural heritage of the Reserves Vincheto di Celarda and Val Tovanella (Belluno province, Italy). Conservation of two protected areas in the context of a LIFE project. Quaderni Conservazione Habitat, 5. Verona: Arti Grafiche Fiorini, 195–217.

Baars JR, Caffery J (2008) Water fern, *Azolla filiculoides* –Under biological control in Ireland. Invasive Species Ireland, Case study 4. 8: 12pp.

Balachowsky A (1949) Faune de France 50: Coléoptères Scolytides. Paris: Librairie de la faculté des sciences. 320 pp.

Balachowsky AS (1963) Entomologie appliquée à l'agriculture, Tome I, Coléoptères, Second Volume. Paris: Masson. 1391 pp.

Barclay MVL (2001) An exotic weevil *Otiorhynchus corruptor* Horst. (Curculionidae). *British Journal of Entomology and Natural History* 14: 160–161.

Barranco P, de la Peña J, Cabello T (1996) El picudo rojo de las palmeras, *Rhynchophorus ferrugineus* (Olivier), nueva plaga en Europa. *Phytoma-España* 67: 36–40.

Base de dados da biodiversidade dos Açores. http://www.azoresbioportal.angra.uac.pt/.

Bitton S, Nakache Y (2000) Red palm weevil in Israel. *Proceedings of date palm international symposium, 2000.02.22–25, Republic Of Namibia*.

Bolu H, Legalov AA (2008) On the Curculionoidea (Coleoptera) fauna of Almond (*Amygdalus communis* L.) orchards in South-eastern and Eastern Anatolia in Turkey. *Baltic J. Coleopterol.* 8: 75–86.

Borges PAV, Vieira V, Dinis F, Jarroca S (2005) List of arthropods (Arthropoda). In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Lisboa: Direcção Regional do Ambiente & Universidade dos Açores, Horta, Angra do Heroísmo & Ponta Delgada, AAPP, 163–221.

Borisch D (1997) Edvard Anderson's Mediterranean greenhouse in Stockholm, an immigration gate for weevils (Curculionidae) from southern Europe. *Entomologisk Tidskrift* 118: 133–134.

Bouget C, Noblecourt T (2005) Short-term development of ambrosia and bark beetle assemblages following a windstorm in French broadleaved temperate forests. *Journal of Applied Entomology* 129: 300–310.

Bright DE (1987) A review of the Scolytidae (Coleoptera) of the Azores with description of a new species of *Phloeosinus*. *Museu Municipal Funchal* 107: 1–5.

Brockerhoff EG, Bain J, Kimberley M, Knizek M (2006) Interception frequency of exotic bark and ambrosia beetles (Coleoptera: Scolytinae) and relationship with establishment in New Zealand and worldwide. *Canadian Journal of Forest Research* 36: 289–298.

Bruge, H (1994) À propos de *Pentarthrum huttoni* Wollaston, 1854 (Coleoptera, Curculionidae, Cossoninae). *Bulletin et Annales de la Société Royale Belge d'Entomologie* 130: 313–323.

Buck FD (1948) *Pentarthrum huttoni* Woll. (Col., Curculionidae) and some imported Cossininae. *Entomologist's Monthly Magazine* 84: 152–154.

Caldara R, Diotti L, Regalin R (2004) Prima segnalazione per l'Europa di *Lissorhoptrus oryzophilus* Kuschel (Coleoptera, Curculionoidea, Erirhinidae), temibile parassita di *Oryza sativa* L. *Bollettino di Zoologia Agraria e di Bachicoltura, Serie II* 36: 165–171.

Carrillo AM (1999) El gorgojo del eucalipto en Canarias. *Diario de Avisos (Santa Cruz de Tenerife)*, 1999/07/12.

Charlesworth D, Charlesworth B (1987) Inbreeding depression and its evolutionary consequences. *Annual Review of Ecology and Systematics* 18: 237–268.

Chilahsayeva YA (2008) [First discovery of *Polygraphus proximus* Blandford (Coleoptera: Scolytidae) in Moscow Oblast]. *Bulletin of Moscow Society of Naturalists* 113: 39–41.

Contarini M, Onufrieva KS, Thorpe KW, Raffa KF, Tobin PC (2009) Mate-finding failure as an important cause of Allee effects along the leading edge of an invading insect population. *Entomologia Experimentalis et Applicata* 133: 307–314.

Covassi M (1974) Il *Demyrsus meleoides* Pascoe: un potenziale nemico delle cicadee ornamentali introdotto in Italia (Coleoptera, Curculionidae). *Redia* 55: 211–217.

Covassi M (1991) Il *Phloeosinus armatus* Reitter, coleottero scolitide del cipresso, nuovo per l'Italia. In *Atti del Convegno "Il Cipresso. Proposte di valorizzazione ambientale e produttiva nei paesi mediterranei della Comunità Economica Europea", Firenze (Italy) 12–13 dicembre 1991*, 190–196.

Dal Monte G (1972) Generalità sui principi scientifici e tecnici per una razionale conservazione dei cereali nei magazzini. *Atti del 1° Simposio „La difesa antiparassitaria nelle industrie alimentari e la protezione degli alimenti", Piacenza (Italy) 1972*. Tip. Edit. Piacentina, 91–107.

Dana ED, Viva S (2006) *Stenopelmus rufinasus* Gyllenhal 1835 (Coleoptera: Erirhinidae) naturalized in Spain. *Coleopterists Bulletin* 60: 41–42.

Dieckmann L (1983) Beiträge zur Insektenfauna der DDR, Coleoptera–Curculionidae (Tanymecinae, Leptopiinae, Cleoninae, Tanyrhynchinae, Cossoninae, Raymondionyminae, Bagoinae, Tanysphyrinae). *Beitr Entomol* 33: 257–381.

Duff AG (Ed) (2008) Checklist of Beetles of the British Isles, 2008 edition. Wells: Duff AG. 164 pp.

Ehret JM (1983) *Apion* (*Rhopalapion*) *longirostre*, espèce nouvelle pour la France (Coleoptera, Curculionidae). *L'Entomologiste* 39: 42.

Emerson BC (2008) Speciation on islands: what are we learning? *Biological Journal of the Linnean Society* 95: 47–52.

EPPO (2005) Datasheets on quarantine pests – *Ips cembrae* and *Ips subelongatus*. *EPPO Bulletin* 35: 445–449.

EPPO (2006) EPPO Reporting Services 2006/001, 2006/028, 2006/225, 2006/226, 2006/227.

EPPO (2008) EPPO Reporting Services 2008/220.

Essl F, Rabitsch W (2002) Neobiota in Osterreich. Wien: Umweltbundesamt. 432 pp.

Faccoli M (1998) The North American *Gnathotrichus materiarius* (Fitch) (Coleoptera Scolytidae): an ambrosia beetle new to Italy. *Redia* 81: 151–154.

Faccoli M (2008) First record of *Xyleborus atratus* Eichhoff in Europe, with an illustrated key to European Xyleborini (Coleoptera Curculionidae Scolytinae). *Zootaxa* 1772: 55–62.

Faccoli M, Frigimelica G, Mori N, Petrucco Toffolo E, Vettorazzo M et al. (2009): First record of *Ambrosiodmus* (Hopkins, 1915) (Coleoptera: Curculionidae, Scolytinae) in Europe. *Zootaxa* 2303: 57–60.

Fernandez Carrillo JL, Fernandez Carrillo E, Alonso-Zarazaga MA (2005) [First recording of *Stenopelmus rufinasus* Gyllenhal, 1835 in the Iberian Peninsula (Coleoptera, Erirhinidae)]. *Graellsia* 61: 139–140.

Foster AP, Morris MG, Whitehead PF (2001) *Ixapion variegatum* (Wencker, 1864) (Col., Apionidae) new to the British Isles, with observations on its European and conservation status. *Entomologist's Monthly Magazine* 137: 95–105.

FREDON-Corse (2007) Le charançon rouge du palmier a débarqué en Corse. http://www.fredon-corse.com/actions/surveillance_CR.htm.

Freude H, Harde KW, Lohse GA (1983) Die Kafer Mitteleuropas 11: Familienreihe: Rhynchophora (Schluß). Krefeld: Goecke & Evers Verlag. 342 pp.

Friedman ALL (2006) *Derelomus piriformis* Hoffmann (Curculionoidea: Curculionidae: Curculioninae: Derelomini), a new invasive species in Israel. *Phytoparasitica* 34: 357–359.

Friedman ALL (2009) The vegetable weevil, *Listroderes costirostris* Schoenherr (Curculionidae: Cyclominae): a new invasive pest in Israel. *Phytoparasitica* 37: 331–332.

García R (2003) Coleópteros: nuevos datos sobre la distribución en el archipiélago canario. *Zoras: revista del Centro Asociado Uned La Palma* mayo 2003: 29–36.

Germain JF, Bertaux F, Streito JC (2008) Attaque surprise de *Listroderes difficilis* Germain sur la Côte d'Azur (Coleoptera curculionidae). *L'Entomologiste* 64: 89–90.

Germain JF, Ramel JM, Maury A, Blanchon F (2008) Premier signalement en France d'un coléoptère ravageur des agaves. *PHM-Revue Horticole* 505: 34–36.

Germann C (2004) *Otiorhynchus pinastri* (Herbst, 1795) - ein invasiver Xenobiont aus dem östlichen Europa in der Schweiz (Coleoptera, Curculionidae). *Mitteilungen der Entomologischen Gesellschaft Basel* 54: 110–114.

Gillerfors G (1988) Coleoptera from pulpwood imported to South Sweden from France and Spain. *Entomologisk Tidskrift* 109: 42–45.

Gonzales et al (2002) *Bol. San. Veg. Plagas* 28: 347–355.

Gosik R, Letowski J, Mokrzycki T, Wanat, M (2001) *Lignyodes bischoffi* (Blatchley, 1916) (Coleoptera: Curculionidae) - new to the fauna of Poland. *Wiadomosci Entomologiczne* 20: 43–48.

Haack RA (2001) Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985–2000. *Integrated Pest Management Reviews* 6: 253–282.

Haack R.A (2006). Exotic bark- and wood-boring Coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Research* 36: 269–288.

Hackett D (1998) The fern weevil, *Syagrius intrudens* Waterhouse (Curculionidae) in Cornwall. *The Coleopterist* 7: 20–21.

Haghebaert G (1991) Nieuwe adventieve Coleoptera uit België. *Bull. Annls. R Soc. Belge Entomol.* 127: 347–348.

Halmschlager E, Ladner C, Zabransky P, Schopf A (2007) First record of the wood boring weevil, *Pentarthrum huttoni*, in Austria (Coleoptera: Curculionidae). *Journal of Pest Science* 80: 59–61.

Hansen M (1996) Catalogue of the Coleoptera of Denmark / Katalog over Danmarks biller. Stenstrup: Apollo Books. 231 pp.

Heijerman T, Moraal L, Burgers J, de Goffau L (2003) *Otiorhynchus apenninus*, a new weevil for the Netherlands (Coleoptera: Curculionidae). *Nederlandse Faunistische Mededelingen* 19: 41–48.

Henin JM, Versteirt V (2004) Abundance and distribution of *Xylosandrus germanus* (Blandford 1894) (Coleoptera, Scolytidae) in Belgium: new observations and an attempt to outline its range. *Journal of Pest Science* 77: 57–63.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH et al. (2005) Audit of non-native species in England. English Nature Research Reports 662, English Nature, Peterborough. 82 pp.

Hoffmann A (1950) Faune de France 52: Coléoptères Curculionides (Première partie). Paris: Lechevalier. 486 pp.

Hoffmann A (1954) Faune de France 59: Coléoptères Curculionides (Deuxième partie). Paris: Lechevalier. 722 pp.

Hoffmann A (1958) Faune de France 62: Coléoptères Curculionides (Troisième partie). Paris: Lechevalier. 631 pp.

Holzer (2007) Erstnachweise und Wiederfunde für die Käferfauna der Steiermark (X) (Coleoptera). *Joannea Zoologie* 9: 51–68.

Holzschuh C (1994) *Pityophthorus traegardhi*, ein neuer Borkenkäfer für Österreich und Mitteleuropa (Coleoptera: Scolytidae). *Forstschutz Aktuell, Wien* 15: 4.

Israelson G (1969) Some additions to the Coleopterous fauna of the Canary Islands (Coleoptera). *EOS* 44: 149–157.

Israelson G (1972) Male copulatory organs of Macronesian species of *Aphanarthrum* Wollaston. With designations of lectotypes and descriptions of new taxa (Col. Scolytidae). *Entomologica Scandinavica* 3: 249–257.

Israelson G (1980) Taxonomical and nomenclatural notes on some Canarian Coleoptera. *Vieraea* 9: 183–210.

Israelson G (1990) A key to the Macaronesian Hypoborini, with description of two new species (Coleoptera, Scolytidae). *Bocagiana* 137: 1–11.

Izquierdo I, Martin JL, Zurita N, Arechavaleta M (Eds) (2004) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). 2nd, Consejería de Política Territorial y Medio Ambiente del Gobierno de Canarias. 500 pp.

Janson OE (1921) *Stenopelmus rufinasus* Gyll., an addition to the list of British Coleoptera. *Entomologist's Monthly Magazine* 57: 225–226.

Joakimow D (1904) Prinos kum Bulgarskata fauna na nasekomite Insecta I Coleoptera. *Sbornik narodni umotvoreniya nauka I knizhnina* 20:1–43.

Jordal BH, Beaver RA, Kirkendall LR (2001) Breaking taboos in the tropics: inbreeding promotes colonization by wood-boring beetles. *Global Ecology and Biogeography* 10: 345–357.

Juan C, Emerson BC, Oromi P, Hewitt GM (2000) Colonization and diversification: towards a phylogeographic synthesis for the Canary Islands. *Trends in Ecology and Evolution* 15: 104–109.

Kehat M (1999) Threat to date palms in Israel, Jordan and the Palestinian authority by the red palm weevil, *Rhynchophorus ferrugineus*. *Phytoparasitica* 27: 241–242.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Péré C et al. (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Kirkendall LR (1993) Ecology and evolution of biased sex ratios in bark and ambrosia beetles (Scolytidae). In: Wrensch DL, Ebbert MA (Eds) *Evolution and Diversity of Sex Ratio: Insects and Mites*. New York: Chapman and Hall, 235–345.

Kirkendall LR personal observations.

Kirkendall LR, Dal Cortivo M, Gatti E (2008) First record of the ambrosia beetle, *Monarthrum mali* (Curculionidae, Scolytinae) in Europe. *J. Pest Science* 80: 123–126.

Kirkendall LR, Faccoli M (2010) Bark beetles and pinhole borers (Curculionidae: Scolytinae, Platypodinae) alien to Europe. *ZooKey* (in press).

Knížek M (2004) Fauna Europaea: Scolytinae. In: Alonso-Zarazaga MA (Ed) Fauna Europaea: Curculionidae. Fauna Europaea version 1.1. http://www.faunaeur.org.

Kontodimas D, Oikonomou D, Thymakis N, Menti C, Anagnou-Veroniki M (2006) [New serious pest of palm trees, the coleopterous *Rhynchophorus ferrugineus* (Olivier)]. *Agriculture-crop & animal husbandry*, 1: 54–57.

Kozłowski MW, Knutelski S (2003) First evidence of an occurrence of *Rhopalapion longirostre* in Poland. *Weevil News* 13: 4 pp. http://www.curci.de/Inhalt.html.

Lanteri AA, Marvaldi AE (1995) *Graphognathus* Buchanan a new synonym of *Naupactus* Dejean and systematics of the *N. leucoloma* species group (Coleoptera: Curculionidae). *The Coleopterists Bulletin* 49: 206–228.

Liebhold AM, Tobin PC (2008) Population ecology of insect invasions and their management. *Annual Review of Entomology* 53: 387–408.

Lombardero MJ, Novoa F (1993) [*Liparthrum mandibulare* Wollaston, 1854 (Coleoptera: Scolytidae), the first record from continental Europe]. *Elytron (Barcelona)* 7: 105–110.

Lombardero MJ, Novoa F (1994) Datos faunísticos sobre escolítidos ibéricos (Coleoptera: Scolytidae). *Boletín de la Asociación Española de Entomología* 18: 181–186.

Longo S (2007) Black weevil of agave. *Informatore Agrario Supplemento* 63(39, Supplemento 1): 43.

Lucht W (1985) Überraschende Freilandfunde fremdländischer Käfer in Südhessen. Naturwissenschaftlicher verein Darmstadt Bericht N F 9, 29–32.

Lundberg S (1995) Catalogus Coleopterorum Sueciae. Version 2. Stockholm: Naturhistoriska Riksmuseet & Entomologiska Foreningen. 217 pp.en.

Lundberg S (2006) New and excluded beetle species since 1995 year's Catalogus Coleopterorum Sueciae. *Entomologisk Tidskrift* 127: 101–111.

Machado A, Oromí P (2000) Elenco de los Coleópteros de las Islas Canarias. Monografia 70. La Laguna: Instituto de Estudios Canarios. 308 pp.

Mandelshtam MY, Aguin-Pombo D, Nunes E (2006) *Hylastes attenuatus* Erichson 1836 (Coleoptera, Scolytidae), an exotic bark beetle new to Madeira Fauna. *Coleopterists Bulletin* 60: 297–298.

Mandelshtam MY, Popovichev BG (2000) [An annotated list of Scolytidae species of Leningradkaya Oblast]. *Entomological Review* 79: 599–618.

Mansilla JP (1992) Presencia sobre *Eucalyptus globulus* Labill de *Gonipterus scutellatus* Gyll. (Col. Curculionidae) en Galicia. *Boletin de Sanidad Vegetal, Plagas* 18: 547–554.

Mansilla JP, Pérez Otero R (1996) El defoliador del eucalipto *Gonipterus scutellatus*. *Phytoma España* 81: 36–42.

MAPA (2006) Orden de 10 de febrero de 2006 por la que se adoptan medidas fitosanitarias cautelares previas para evitar la propagación del curculiónido ferruginosos entre la palmera canaria. *Boletín Oficial de Canarias* 30: 3084–3085.

Markovich A (1909) Prinos za izuchaveneto na nasekomnata fauna v razgradksa okolnost. *Sbornik narodni umotvoreniya nauka I knizhnina* 25: 1–20.

Mazur M (2002) The distribution and ecology of weevils (Coleoptera: Nemonychidae, Attelabidae, Apionidae, Curculionidae) in western Ukraine. *Acta zoologica cracoviensia* 45: 213–244.

Menet D (1998) Confirmed presence of *Euophryum confine* (Broun) (Col. Curculionidae, Cossoninae) in France. *Bulletin de la Société Entomologique de France* 103: 286.

Meregalli M (2004) Fauna Europaea: Cyclominae. In: Alonso-Zarazaga MA (Ed) Fauna Europaea: Curculionidae. Fauna Europaea version 1.1. http://www.faunaeur.org.

Mifsud D, Knížek M (2009) The bark beetles (Coleoptera: Scolytidae) of the Maltese Islands (Central Mediterranean). *Bulletin of the Entomological Society of Malta* 2: 25–52.

Moncoutier B (1982) Un nouveau curculionide en France. *L'Entomologiste* 38: 206.

Moraal, LG (2006) Insectenplagen op bomen en struiken in 2005. *Vakblad Natuur, Bos en Landschap* 3: 12–15.

Moraal, LG (2009) Infestations of the Japanese thuja bark beetle *Phloeosinus rudis* (Col., Scolytidae) in The Netherlands. In *International Congress on Biological Invasions (ICBI), Fuzhou (China), 2–6 November, 2009*.

Morris MG (1990) Orthocerous weevils: Coleoptera: Curculionoidea (Nemonychidae, Anthribidae, Urodontidae, Attelabidae and Apionidae). Handbooks for the Identification of British Insects 5(16). 108 pp.

Morris MG (2002) True weevils (part I): Coleoptera: Curculionidae: (subfamilies Raymondionyminae to Smicronychinae). Handbooks for the Identification of British Insects 5(17b). 149 pp.

Morrone JJ (1993) Systematic revision of the *costirostris* species group of the weevil genus *Listroderes* Schoenherr (Coleoptera, Curculionidae). *Transactions of the American Entomological Society* 119: 271–315.

Mphuru AN (1974) *Araecerus fasciculatus* de Geer (Coleoptera: Anthribidae): A review. *Trop. Stored Prod. Inf.* 26: 7–15.

Neid J (2003) Présence en Haute-Corse de *Gonipterus scutellatus* Gyllenhal 1833 (Coleoptera, Curculionidae, Cyclominae, Gonipterini). *L'Entomologiste* 59: 103.

Noblecourt T (2004) Note sur les Coléoptères Scolytidae : espèces rares ou peu communes en France. *Coléoptériste* 7: 33–36.

O'Brien CW, Wibmer GJ (1982) Annotated checklist of the weevils (Curculionidae sensu lato) of North America, Central America, and the West Indies (Coleoptera: Curculionoidea). Memoirs of the American Entomological Institute (Gainesville) 34. 382 pp.

O'Connor JP (1977) Occurrence of *Euophryum rufum* Broun (Col., Curculionidae) in Ireland. *Entomologist's Monthly Magazine* 113: 56.

Oberprieler RG, Marvaldi AE, Anderson RS (2007) Weevils, weevils, weevils everywhere. *Zootaxa* 1668: 491–520.

Obretenchev D, Atanasov H, Tzalev M, Kirilov L (1990) Razprostranenie na nyakoi vunshnokarantinni vrediteli po skladiranite hrani I produkti ot rastitelen proizhod v Bulgaria. *Nauchni docladi i suobshteniya, SSA, S.* III: 172–178.

Ólafsson E (1991) A checklist of Icelandic insects. *Fjolrit Natturufraedistofnunar* 17: 1–69.

OPIE (2002) Listes de références - Faune de la France métropolitaine. Coléoptères Scolytidae. http://www.inra.fr/opie-insectes/observatoire/listes/l_scolyt.htm.

Oromí P, García R (1995) Contribución al conocimiento de la fauna de coleópteros de Canarias y su distribución. *Vieraea* 24: 175–186.

Paiva MR (1996) Management of forest insects in Portugal. *XX International Congress of Entomology, Firenze (IT), 1996/08/25–31*. Abstract 16–026, 510.

Palm, E (1996) Nordeuropas snudebiller 1: De kortsnudende arter (Coleoptera: Curculionidae) - med sarligt henblik pa den danske fauna. Danmarks Dyreliv 7. 356 pp.

Peer K, Taborsky M (2005) Outbreeding depression, but no inbreeding depression in haplodiploid ambrosia beetles with regular sibling mating. *Evolution* 59: 317–323.

Pennacchio F, Faggi M, Gatti E, Caronni F, Colombo M et al. (2004) First record of *Phloeotribus liminaris* (Harris) from Europe (Coleoptera Scolytidae). *Redia* 87: 85–89.

Pennacchio F, Roversi PF, Francardi V, Gatti E (2003) *Xylosandrus crassiusculus* (Motschulsky) a bark beetle new to Europe. *Redia* 86: 77–80.

Perrin H (1984) Présence en France d'*Apion* (*Rhopalapion*) *longirostre* (Olivier) (Coleoptera, Curculionidae, Apioninae) et répartition dans la région paléarctique. *L'Entomologiste* 40: 269–274.

Perrin H (1995) *Rhopalapion longirostre* (Olivier) (Coleoptera: Apionidae): 12 années de recoltes en France. *L'Entomologiste* 51: 220.

Pfeffer A (1995) Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypodidae). *Entomologica Basiliensia* 17: 5–310.

Piel F, Grégoire JC, Knížek, M (2006) New occurrence of *Ips duplicatus* Sahlberg in Herstal (Liege, Belgium). Bulletin *OEPP* 36: 529–530.

Pimentel D (1991) World resources and food losses to pests. In: Gorham JR (Ed) *Ecology and Management of Food Industry Pests, FDA Technical Bulletin 4*. Gaithersburg: of Official Analytical Chemists, 5–11.

Piry S, Gompel N (2002) Présence en France de *Neoderelomus piriformis* (Hoffmann, 1938) sur le palmier *Phoenix canariensis* Hort. (Coleoptera, Curculionidae, Derelomini). *Bulletin de la Société entomologique de France* 107: 529–534.

Rabasse JM, Perrin H (1979) Introduction en France du charançon de l'eucalyptus, *Gonipterus scutellatus* Gyll. (Col., Curculionidae). *Annales de Zoologie, Écologie Animale* 11: 336–345.

Ragusa E (1924) Gli Ipidae della Sicilia. *Bollettino Società Entomologica Italiana* 56: 114–118.

Ranger CM, Reding ME, Persad AB, Herms DA (2010) Ability of stress-related volatiles to attract and induce attacks by *Xylosandrus germanus* and other ambrosia beetles. *Agricultural and Forest Entomology* 12: 177–185.

Rasmussen, S (1976) Traeborende snudebille, *Pentarthrum huttoni* Woll. (Coleoptera, Curculionidae) ny for Danmark. *Entomologiske Meddr.* 44: 107–109.

Ratzeburg JTC (1837) Die Forst-Insecten oder Abbildung und Beschreibung der in den Wäldern Preussens und der Nachbarstaaten als schädlich oder nützlich bekannt gewordenen Insecten. Erster Theil, Die Käfer. Berlin: Nicolai. 212 pp.

Reitter E (1916) Fauna Germanica, Die Käfer des Deutschen Reiches, V. Band. Schriften des Deutschen Lehrervereins für Naturkunde, XXXIII. Stuttgart: Band. K. G. Lutz. 343 pp.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biol. Inv.* 9: 629–643.

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W et al. (2009) Alien Terrestrial Invertebrates of Europe. In: DAISIE, *Handbook of Alien Species in Europe, Invading nature: springer series in invasion ecology 3*. Springer Science + Business Media B.V., 63–79.

Runge JB (2008) *Otiorhynchus apenninus* Stierlin, 1883, *Otiorhynchus dieckmanni* Magnano, 1979 and *Otiorhynchus aurifer* Boheman, 1843, three new weevils to the Danish fauna. *Entomologiske Meddelelser* 76: 69–78.

Sacchetti P, Camèra A, Granchietti A, Rosi MC, Marzialetti P (2005) Prima segnalazione in Italia del curculionide delle palme, *Rhynchophorus ferrugineus*. http://www.cespevi.it/art/rhynco.htm.

Salomone Suárez F, Carnero Hernández A, Marrero Ferrer M, González Hernández A (2000) Presence in the palearctic zone of *Diocalandra frumenti* Fabricius, (Coleoptera, Curculionidae). *Boletín de la asociación Espaňola de Entomología* 24, 263–264.

Sampò A (1976) An Australian gonipterine weevil defoliator of eucalyptus in Europe for the first time (Coleoptera Curculionidae). *Il Floricultore* 13, 3 pp.

Sampò A, Olmi M (1975) Un pericoloso nenìico delle palme nuovo per l'Italia: *Dactylotrypes uyttenbogaarti* Eggers 1927 (Coleoptera Scolytidae). *Ann. Fac. Se. Agr. Univ. degli Studi di Torino* IX, 431–446.

Schedl KE (1946) Bestimmungstabellen der palaearktischen Borkenkäfer, I. Die Gattung *Crypturgus* Er. *Zentralblatt für das Gesamtgebiet der Entomologie* 1: 1–15.

Schedl KE (1963) XX. Scolytidae von Madeira. *Societas Scientiarum Fennica, Commentationes Biologicae* 25: 154–156.

Schedl KE (1970) Zur Synonymie der Borkenkäfer XX. 272. Beitrag zur Morphologie und Systematik der Scolytoidea. *Annales der Naturhististorische Museum Wien* 74, 221–231.

Schedl KE, Lindberg H, Lindberg H (1959) Coleoptera insularum Canariensium II. Scolytidae. *Societas Scientiarum Fennica, Commentationes Biologicae* 20: 1–34.

Schott C (2004) Sur la répartition de *Xyleborus peregrinus* Eggers en France et en Allemagne. *Bulletin de la Société Entomologique de Mulhouse* 60: 19–36.

Schott C, Callot HH (1994) Trois coléoptères scolytides nouveaux pour la faune de France observés en Alsace (*Xyleborus peregrinus* Eggers, *Lymantor aceris* Lindemann, *Phloeotribus caucasicus* Reitter, Col. Scolytidae). *Bulletin de la Société Entomologique de Mulhouse* 1994: 67–70.

Sebelin C (1951) Zum auftreten von *Araecerus fasciculatus* in Hamburg. *Zucker-u. Susswaren-Wirt* 4: 656–658.

Sheppard AW, Shaw RH, Sforza R (2006) Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research* 46, 93–117.

Silfverberg H (2004) Enumeratio nova Coleopterorum Fennoscandiae, Daniae et Baltiae. *Sahlbergia* 9: 1–111.

Silfverberg H (2004) Country records accidentally omitted from the new check list are added. *Sahlbergia* 9: 122.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP et al. (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology* 9: 307–326.

Solari A, Solari F (1908) Segnalato come *Asynonychus godmani* Crotch, 1867. *Bollettino Società entomologica italiana* 40:268.

Stachowiak P, Wanat M (2001) Pierwsze stwierdzenie *Pentarthrum huttoni* Wollaston w Polsce, oraz klucz do oznaczania srodkowoeuropejskich rodzajów Cossoninae (Coleoptera, Curculionidae). *Wiad Ent Poznan* 20: 33–41.

Stauffer C, Kirisits T, Nussbaumer C, Pavlin R, Wingfield MJ (2001) Phylogenetic relationships between the European and Asian eight spined larch bark beetle populations (Coleoptera, Scolyltidae) inferred from DNA sequences and fungal associates. *European Journal of Entomology* 98: 99–105.

Strejček J (1993) Curculionidae. In Jelínek J (ed) *Check-list of Czechoslovak insects IV (Coleoptera). Seznam československých brouků*. Folia Heyrovskyana, Supplement 1, 135–152.

Stüben PE (2003) The Rediscovery of *Acalles droueti* Crotch 1867 and Curculionoidea collected on an excursion on the Azores: A Report (Coleoptera: Curculionidae: Cryptorhynchinae). Weevil News 16. 10 pp. http://www.curci.de/Inhalt.html.

Targioni Tozzetti A (1884) Relazioni intorno ai lavori della Regia Stazione di Entomologia Agraria di Firenze per gli anni 1879, 1880, 1881, 1882. *Annali di Agricoltura del R. Ministero Agricoltura, Industria e Commercio, Roma*: 1–645.

Telfer MG (2007) *Macrorhyncolus littoralis* (Broun) (Curculionidae) new to Ireland. *Coleopterist* 16: 118–119.

Teodorescu I, Manole T, Iamandei M (2006) The main alien/invasive insect species in Romania. *Romanian Journal of Biology - Zoology* 51: 43–61.

The World Factbook: Washington, DC: Central Intelligence Agency, 2009. https://www.cia.gov/library/publications/the-world-factbook/index.html.

Tobin PC, Whitmire SL, Johnson DM, Bjornstad ON, Liebhold AM (2007) Invasion speed is affected by geographical variation in the strength of Allee effects. *Ecology Letters* 10: 36–43.

Tomov R, Trencheva K, Trenchev G, Çota E, Ramafhi A et al. (2009) Non-Indigenous Insects and their Threat to Biodiversity in Albania, Bulgaria and Republic of Macedonia. Sofia: Pensoft Publishers.

Tremblay E, Espinosa B, Mancini D, Caprio G (2000) Un coleottero proveniente dal Sudamerica minaccia i pioppi. *L'informatore Agrario* 48: 89–90.

Valkama H, Martikainen P, Raty M (1997) First record of North American ambrosia beetle *Gnathotrichus materiarius* (Fitch) (Coleoptera, scolytidae) in Finland - a new potential forest pest? *Entomologica fennica* 8: 193–195.

Valladares L, Cocquempot C (2008) Présence en France d'Otiorhynchus (*Nehrodistus*) *corruptor* (Host, 1789) (Coleoptera Curculionidae). *L'Entomologiste*, 64: 129–130.

Welch RC (1990) *Macrorhyncolus littoralis* new record Broun Coleoptera Curculionidae, a littoral weevil new to the palearctic region from two sites in Kent England UK. *Entomologist's Monthly Magazine* 126: 97–101.

Whitehead PF, Zach P, Kulfan J, Cicak A, Cunderlik I (2000) *Dactylotrypes longicollis* (Wollaston 1864) (Coleoptera, Scolytidae) introduced to the Slovak Republic. *Anzeiger für Schadlingskunde*.

Table 8.2.1. Characteristics of the Curculionoidea species alien *to* Europe. Asterisks indicate *presumed* aliens. Feeding habits and hosts are those of larvae, which are generally the more damaging stage[6]. Country codes abbreviations refer to ISO 3166, with extensions (see Appendix I); main Atlantic and Mediterranean islands are treated separately as special „countries". **N/A** data non available. Status: **A** alien *to* Europe **C** *cryptogenic*. Feeding habits: abbreviations between brackets specify the feeding habits; **her** *herbiphagous* (larvae bore and feed inside non woody tissue of plant stems or leaves; stem includes branches, twigs, collar, bulb and rootstock) **lbw** *leaf/stem browser* (larvae externally feed on leaves or stems, as most caterpillars; early stages could be miner) **phl** *phloeophagous* (larvae bore and feed inside tree inner bark) **rbo** *root borer* (larvae bore and feed inside roots) **rbw** *root browser* (subterranean larvae externally feed on roots; early stages could be root miner) **spe** *spermatophagous* (larvae bore and feed inside reproductive organs, generally seeds) **xmp** *xylomycetophagous* (larvae live in galleries bored by females inside wood and mainly feed on wood-decaying symbiotic fungi) **xyl** *xylophagous* (larvae bore and feed inside wood, including woody materials such as palm stems)[7]. Native range: the field contains standardized range; if useful, native range could be specified between brackets. 1st record in Europe: date and countries of first known specimen, or first publication. Habitat: habitats in invaded countries; abbreviations refer to EUNIS (see Appendix II). Hosts: recorded hosts in invaded countries, and, between brackets, host breath in native range; host breath in native range is given as *monophagous*, *oligophagous* or *polyphagous* (abbreviated as **mp**, **op** and **pp**), depending if the species normally attacks hosts in one genera, one family or more; **hpp**: *highly polyphagous*.

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Anthribidae								
Araecerus coffeae (Fabricius 1801)	A	phyto-phagous (spe)	Asia-Tropical	1951, DE	AT, BG, DE, FR, GB, IL, IT, MT, PL	J1	stored products (pp: *Coffea*, *Camellia sinensis*, stored products)	Essl and Rabitsch (2002), Mphuru (1974), Obretenchev et al. (1990), Sebelin (1951)
Apionidae								
Alocentron (*Alocentron*) *curvirostre* (Gyllenhal 1833)	A	phyto-phagous (spe)	Asia-Temperate	1904, BG	AT, BG, CH, CZ, HU, IT-SIC, MD, PL, RO, RS, SI, SK	I2, FA, FB	*Alcea rosae* (op: Malvaceae)	Essl and Rabitsch (2002), Joakimow (1904), Wittenberg (2005)
Aspidapion (*Aspidapion*) *validum* (Germar 1817)	A	phyto-phagous (spe)	Asia-Temperate	1960, BG	AT, BG, CH, CZ, DE, FR, HR, HU, IT, MD, PL, PT, RO, SK, UA	I2, FA, FB	*Alcea rosae* (op: Malvaceae)	Abbazzi et al. (1994), Angelov (1960), Essl and Rabitsch (2002), Wittenberg (2005)

6 Platypodines and scolytines adults generally feed as larvae, as do adults of many other species with *spermatophagous* or xylophagous *sensu lato*[7] larvae. Otherwise adults generally feed externally on leaf and stem regardless of the larval habits. Adults are often more polyphagous than larvae, except platypodines and scolytines.

7 We use the term xylophagous *sensu lato* to gather species with *phloeophagous*, *xylomycetophagous* and *xylophagous* larvae.

Family / *subfamily* Species	Status	Feeding habits	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Rhopalapion longirostre (Olivier 1807)	A	phyto-phagous (spe)	Asia-Temperate	1875, RO	AT, BG, CH, CY, CZ, ES, FR, FR-COR, DE, GR, GR-NEG, HR, HU, IT, MD, NL, PL, RO, RS, SK, UA	I2	*Alcea rosae* (op: Malvaceae)	Abbazzi et al. (1994), Ehret (1983), Essl and Rabitsch (2002), Kozłowski and Knutelski (2003), Markovich (1909), Mazur (2002), Perrin (1984), Perrin (1995), Wittenberg (2005)
Curculionidae								
Cossoninae								
Amaurorhinus (Amaurorhinus) monizianus (Wollaston 1860)*	A	phyto-phagous	Africa (ES-CAN)	N/A	PT-AZO, PT-MAD	B	N/A (*Suaeda*, *Salsola*)	Base de dados da biodiversidade dos Açores, Oromí and García (1995)
Caulophilus oryzae (Gyllenhal 1838)	A	phyto-phagous (spe)	North America	1982, PT-MAD	ES-CAN, GB, PT-MAD	J1	grain, stored products (pp: grain, *Persea* seed)	Izquierdo et al. (2004), Morris (2002), O'Brien and Wibmer (1982)
Euophryum confine (Broun 1880)	A	phyto-phagous (xyl)	Australasia	1937, GB	AD, AT, CZ, ES, ES-BAL, FR, GB, HU, PT, SE	J1, I2	decaying wood (pp: decaying wood)	Essl and Rabitsch (2002), Hill et al. (2005), Menet (1998)
Euophryum rufum (Broun 1880)	A	phyto-phagous (xyl)	Australasia	1934, GB	CH, DK, ES, GB, IE, SE	J1, I2	decaying wood (pp: decaying wood)	Hill et al. (2005), O'Connor (1977)
Macrorhyncolus littoralis (Broun 1880)	A	phyto-phagous (xyl)	Australasia	1987, GB	GB, IE	B2	driftwood (pp: decaying wood)	Morris (2002), Telfer (2007), Welch (1990)
Pentarthrum huttoni Wollaston 1854	A	phyto-phagous (xyl)	Australasia	1854, GB	AT, BE, CH, DE, DK, ES, FR, GB, IE, IT, NL, PL, RU, SK	J1	decaying wood (pp: decaying wood)	Abbazzi and Osella (1992), Bruge (1994), Buck (1948), Dieckmann (1983), Halmschlager et al. (2007), Hoffmann (1954), Rasmussen (1976), Stachowiak and Wanat (2001), Strejček (1993), Wittenberg (2005)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pentatemnus arenarius Wollaston 1861*	A	phytophagous	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Cryptorhynchinae								
Rhyephenes humeralis (Guérin-Méneville 1830)	A	phytophagous (phl)	C & S America	2003, ES	ES	G1, G5, X11	*Pinus radiata* (pp: broadleaf trees)	Alonso-Zarazaga and Goldarazena (2005)
Curculioninae								
Lignyodes (*Lignyodes*) *bischoffi* (Blatchley 1916)	A	phytophagous (spe)	North America	2001, PL	AT, PL	G, I2	*Fraxinus* (op: *Fraxinus*, *Syringa*)	Essl and Rabitsch (2002), Freude et al. (1983), Gosik et al. (2001)
Neoderelomus piriformis (Hoffmann 1938)	A	phytophagous (spe)	Africa (North)	1992, IT, IT-SIC	ES, ES-CAN, FR, IL, IT, IT-SIC, PT-MAD	I2	*Phoenix canariensis* (*Phoenix*)	Abbazzi and Osella (1992), Alonso-Zarazaga and Lyal (1999), Friedman (2006), Machado and Oromí (2000), Piry and Gompel (2002)
Tychius (Tychius) antoinei Hustache 1932*	A	phytophagous	Africa (North)	N/A	ES-CAN	N/A	N/A (Fabaceae)	Machado and Oromí (2000)
Tychius (Tychius) depauperatus Wollaston 1864*	A	phytophagous	Africa (North)	N/A	ES-CAN	N/A	N/A (Fabaceae)	Machado and Oromí (2000)
Cyclominae								
Asperogronops inaequalis (Boheman 1842)	A	phytophagous (lbw)	Asia-Temperate	1946, SE	DE, DK, FI, FR, GB, LT, LV, NL, SE	I2	*Atriplex* (op: Chenopodiaceae)	Meregalli (2004)
Gonipterus scutellatus Gyllenhal 1833	A	phytophagous (lbw)	Australasia	1975, IT	ES, ES-CAN, FR, FR-COR, IT, PT	I2, G2	*Eucalyptus* (mp: *Eucalyptus*)	Abbazzi and Osella (1992), Arzone (1976), Carrillo (1999), Machado and Oromí (2000), Mansilla (1992), Mansilla and Pérez Otero (1996), Neid (2003), Paiva (1996), Rabasse and Perrin (1979), Sampò (1976)

Family / *subfamily* Species	Status	Feeding habits	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Listroderes costirostris Schoenherr 1826	A	phyto-phagous (lbw)	C & S America	1950, ES-CAN	ES-BAL, ES-CAN, FR, IL, PT	I, J100	N/A (hpp: vegetables, weeds)	Balachowsky (1963), Friedman (2009), Germain et al. (2008a), Machado and Oromí (2000), Moncoutier (1982)
Entiminae								
Asynonychus godmani Crotch 1867	A	phyto-phagous (rbw)	C & S America	1908, IT	DK, ES, ES-BAL, ES-CAN, FR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, SE	I	N/A (pp: *Rosa*, ornamentals, fruit trees)	Hoffmann (1950), Machado and Oromí (2000), Solari and Solari (1908), Stüben (2003)
Naupactus leucoloma Boheman 1840	A	phyto-phagous (rbw)	C & S America	2003, PT-AZO	PT-AZO	I, G	N/A (hpp: Fabaceae, vegetables, *Zea mays*)	Borges et al. (2005)
Sitona (Sitona) latipennis Gyllenhal 1834*	A	phyto-phagous (rbw)	Africa (PT-MAD)	N/A	ES-CAN	N/A	*Foeniculum* (N/A)	García (2003), Machado and Oromí (2000)
Hyperinae								
Donus (Donus) fallax (Capiomont 1868)*	A	phyto-phagous (lbw)	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Donus (Antidonus) isabellinus (Boheman 1834)*	A	phyto-phagous (lbw)	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Lixinae								
Pycnodactylopsis (Louwia) tomentosa (Fåhraeus 1842)*	A	phyto-phagous	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Molytinae								
Demyrsus meleoides Pascoe 1872	A	phyto-phagous (xyl)	Australasia	1974, IT	IT	I2	Cycadales (op: Cycadales)	Covassi (1974)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Styphloderes (Parastyphloderes) lindbergi Roudier 1963*	A	phytophagous	Africa (ES-CAN)	N/A	PT-MAD	N/A	N/A (N/A)	Oromí and García (1995)
Syagrius intrudens Waterhouse 1903	A	phytophagous (her)	Australasia	1998, GB	GB	J100	Pteridopsida (op: Pteridopsida)	Hackett (1998), Hill et al. (2005)
Platypodinae								
Megaplatypus mutatus (Chapuis 1865)	A	phytophagous (xmp)	C & S America	2000, IT	IT	G1, I2	*Populus* (pp: broadleaf trees)	Tremblay et al. (2000)
Scolytinae								
Ambrosiodmus rubricollis Eichhoff 1875	A	phytophagous (xmp)	Asia	2008, IT	IT	G	*Aesculus hippocastanum, Prunus persica* (pp: broadleaf trees)	Faccoli et al. (2009)
Aphanarthrum affine Wollaston 1860*	A	phytophagous (her)	Africa	1860, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)
Aphanarthrum bicinctum Wollaston 1860*	A	phytophagous (her)	Africa	1860, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)
Aphanarthrum bicolor Wollaston 1860*	A	phytophagous (her)	Africa (ES-CAN)	1972, PT-MAD	PT-MAD	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)
Aphanarthrum mairei Peyerimhoff 1923*	A	phytophagous (her)	Africa	1928, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1980)
Aphanarthrum piscatorium Wollaston 1860*	A	phytophagous (her)	Africa (ES-CAN)	1972, PT-MAD	PT-MAD	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Cisurgus wollastonii (Eichhoff 1878)*	A	phyto-phagous (her)	Africa	1860, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Schedl (1946)
Coccotrypes carpophagus (Hornung 1842)	A	phyto-phagous (spe)	Tropical, subtropical	N/A	ES-CAN, PT-AZO, PT-MAD	I2	*Phoenix*, *Washingtonia*, Arecaceae, *Dracaena* (pp: Arecaceae, woody seeds)	Bright (1987), Kirkendall per. obs.
Coccotrypes dactyliperda (Fabricius 1801)	A	phyto-phagous (spe)	Tropical, subtropical	1884, IT	ES-CAN, FR, FR-COR, HU, IT, IT-SAR, IT-SIC, MT, PT-MAD	I2	*Phoenix*, *Chamaerops umilis*, Arecaceae (pp: Arecaceae, woody seeds)	Kirkendall and Faccoli (2010), Schedl (1963), Schedl et al. (1959), Targioni Tozzetti (1884)
Coleobothrus alluaudi (Peyerimhoff 1923)*	A	phyto-phagous (her)	Africa	1928, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1980)
Cyclorhipidion bodoanus (Reitter 1913)	A	phyto-phagous (xmp)	Asia	1960, FR	BE, CH, DE, FR, IT, NL	G1	*Quercus* (op: Fagaceae)	Audisio et al. (2008), Bouget and Noblecourt (2005), Kirkendall and Faccoli (2010), Schott (2004), Schott and Callot (1994)
Dactylotrypes longicollis (Wollaston 1864)	A	phyto-phagous (spe)	Africa (ES-CAN)	1949, FR-COR	ES, FR, FR-COR, HR, IT, IT-SIC, PT-MAD	I2	*Phoenix canariensis*, Arecaceae, *Dracaena draco* (op: Arecaceae, Dracaenaceae)	Balachowsky (1949), Lombardero and Novoa (1994), Sampò and Olmi (1975), Whitehead et al. (2000)
Dryocoetes himalayensis Strohmeyer 1908	A	phyto-phagous (phl)	Asia-Temperate	2004, FR	CH, FR	G	N/A (pp: *Juglans regia*, *Pyrus lanata*)	Knížek (2004)
Gnathotrichus materiarius (Fitch 1858)	A	phyto-phagous (xmp)	North America	1933, FR	BE, CH, CZ, DE, ES, FI, FR, IT, NL, SE	G	*Picea*, *Pinus* (pp: conifers)	Balachowsky (1949), Faccoli (1998), Kirkendall and Faccoli (2010), Valkama et al. (1997), Wittenberg (2005)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hypocryphalus scabricollis (Eichhoff 1878)	A	phyto-phagous (phl)	Asia	1991, MT	MT	I2	*Ficus* (pp)	Mifsud and Knížek (2009)
Hypothenemus crudiae (Panzer 1791)	A	phyto-phagous (phl)	C & S America (+ North Am.)	N/A	PT-AZO	G1	N/A (hpp)	Base de dados da biodiversidade dos Açores
Hypothenemus eruditus Westwood 1836	A	phyto-phagous (phl, spe)	C & S America (+ North Am.)	1924, IT-SIC	ES, ES-CAN, FR, FR-COR, IL, IT, IT-SIC, MT, PT-AZO, PT-MAD	J1	N/A (hpp)	Balachowsky (1949), Machado and Oromí (2000), Noblecourt (2004), Pfeffer (1995), Ragusa (1924), Roll et al. (2007)
Liparthrum artemisiae Wollaston 1854*	A	phyto-phagous (phl)	Africa (ES-CAN)	N/A	PT-MAD	F5	*Artemisia* (mp: *Artemisia*)	Schedl (1963)
Liparthrum bituberculatum Wollaston 1854*	A	phyto-phagous (phl)	Africa (North)	N/A	ES-CAN, PT-MAD	G1	*Laurus* (mp: *Laurus*)	Israelson (1990)
Liparthrum curtum Wollaston 1854*	A	phyto-phagous (phl)	Africa (ES-CAN)	N/A	PT-AZO, PT-MAD	G1	*Castanea*, *Ficus* (pp: Euphorbiaceae, Moraceae, Fabaceae, Fagaceae)	Israelson (1990)
Liparthrum inarmatum Wollaston 1860*	A	phyto-phagous (her)	Africa	N/A	ES-CAN, PT-MAD	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1990)
Liparthrum mandibulare Wollaston 1854	A	phyto-phagous (phl)	Africa (ES-CAN)	N/A	ES, GB, PT-MAD	G1	*Alnus*, *Betula*, *Castanea*, *Euphorbia*, *Erica*, *Quercus*, *Rubus* (hpp)	Israelson (1990), Lombardero and Novoa (1993)
Monarthrum mali (Fitch 1855)	A	phyto-phagous (xmp)	North America	2007, IT	IT	G	N/A (pp: broadleaf trees)	Kirkendall et al. (2008)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Phloeosinus rudis Blandford 1894	A	phyto-phagous (phl)	Asia	1940, FR	FR, NL	FA, G5	*Thuja*, *Chamaecyparis*, *Juniperus chinensis*, Cupressaceae (op: Cupressaceae)	Balachowsky (1949), Moraal (2009)
Phloeotribus liminaris (Harris 1852)	A	phyto-phagous (phl)	North America	2004, IT	IT	I2	*Prunus serotina* (mp: *Prunus*)	Pennacchio et al. (2004)
Polygraphus proximus Blandford 1894	A	phyto-phagous (phl)	Asia	2000, RU	RU	G3	*Abies* (mp: *Abies*)	Chilahsayeva (2008), Mandelshtam and Popovichev (2000)
Xyleborinus attenuatus Wood & Bright 1992	A	phyto-phagous (xmp)	Asia	1987, AT, CZ	AT, CH, CZ, DE, ES, HU, NL, PL, RU, SE, SK, UA	G1	*Alnus*, *Betula*, *Salix*, *Tilia*, *Quercus*, *Corylus*, broadleaf trees (pp: broadleaf trees)	Essl and Rabitsch (2002), Kirkendall and Faccoli (2010)
Xyleborus affinis Eichhoff 1868	A	phyto-phagous (xmp)	C & S America (+ North Am.)	2006, AT	AT	I	*Dracaena* (pp: broadleaf trees)	Holzer (2007)
Xyleborus atratus Eichhoff 1875	A	phyto-phagous (xmp)	Asia	2007, IT	IT	G	N/A: *Quercus*? (pp: broadleaf trees)	Faccoli (2008)
Xyleborus pfeilii (Ratzeburg 1837)[8]	A	phyto-phagous (xmp)	Asia	1837, DE	AT, BG, CH, CZ, DE, ES, FR, HR, HU, IT, PL, SI, SK, UA	G	*Alnus*, *Betula*, *Populus* (pp: broadleaf trees)	Kirkendall and Faccoli (2010), Ratzeburg (1837)
Xylosandrus crassiusculus (Motschulsky 1866)	A	phyto-phagous (xmp)	Asia	2003, IT	IT	G2, J100	*Ceratonia siliqua* (pp: broadleaf trees, *Pinus*)	Pennacchio et al. (2003)

[8] *Xyleborus pfeilii* was until recently treated as native to Europe, but is now thought to be introduced (Kirkendall and Faccoli 2010).

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Xylosandrus germanus (Blandford 1894)	A	phytophagous (xmp)	Asia	1950, DE	AT, BE, CH, CZ, DE, FR, HU, IT, NL, PL, RU, SI	G	*Fagus*, *Castanea*, *Buxus*, *Ficus*, *Carpinus*, *Quercus*, *Juglans*, *Picea*, *Pinus* (pp: broadleaf trees, conifers)	Henin and Versteirt (2004), Kirkendall and Faccoli (2010)
Xylosandrus morigerus (Blandford 1894)	A	phytophagous (xmp)	Asia	1916, AT, CZ, FR, GB	AT, CZ, FR, GB, IT	J100	greenhouse orchids as *Dendrobium* (pp: broadleaf trees)	Kirkendall and Faccoli (2010), Reitter (1916)
Dryophthoridae								
Cosmopolites sordidus (Germar 1824)	A	phytophagous (xyl)	Asia-Tropical	2004, ES-CAN	ES-CAN, PT-AZO, PT-MAD	I	N/A (op: *Musa*, *Ensete*)	Machado and Oromí (2000)
Diocalandra frumenti (Fabricius 1801)	A	phytophagous (xyl)	Asia-Tropical	1998, ES-CAN	ES-CAN	I2	*Phoenix*, Arecaceae (op: Arecaceae)	Gonzales et al. (2002), Machado and Oromí (2000), Salomone Suárez et al. (2000)
Paradiaphorus crenatus (Billberg 1820)	A	phytophagous (xyl)	C & S America	2004, ES-CAN	ES-CAN	I1	N/A (*Ananas*)	Machado and Oromí (2000)
Rhynchophorus ferrugineus (Olivier 1790)	A	phytophagous (xyl)	Asia-Tropical	1993, ES	CY, ES, ES-CAN, FR, FR-COR, GR, GR-CRE, GR-SEG, IL, IT, IT-SAR, IT-SIC	X24, I2	Arecaceae (op: Arecaceae)	Barranco et al. (1996), Bitton and Nakache (2000), EPPO (2006), FREDON-Corse (2007), Kehat (1999), Kontodimas et al. (2006), MAPA (2006), Sacchetti et al. (2005)
Scyphophorus acupunctatus Gyllenhal 1838	A	phytophagous (her)	C & S America	2006, IT-SIC	FR, IT-SIC	I2	*Agave* (pp: Agavaceae, Dracaenaceae)	Germain et al. (2008b), Longo (2007)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sitophilus linearis (Herbst 1797)	A	phyto-phagous (spe)	Tropical, subtropical	1954, FR-COR	AL, AT, ES-CAN, FR, FR-COR, IT, PL	J1	*Tamarindus indica* (mp: *Tamarindus indica*)	Abbazzi et al. (1994), Essl and Rabitsch (2002), Hoffmann (1954), Machado and Oromí (2000), Tomov et al. (2009)
Sitophilus oryzae (Linnaeus 1763)	A	phyto-phagous (spe)	Asia-Tropical	1896, SE	AL, AT, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, FR-COR, GB, GL, HR, HU, IS, IT, IT-SAR, IT-SIC, LT, LV, MT, NL, NO, PL, PT, PT-AZO, RO, SE, UA	J1	grain (op: cereal grain)	Abbazzi et al. (1994), Balachowsky (1963), Essl and Rabitsch (2002), Hoffmann (1954), Joakimow (1904), Machado and Oromí (2000), Silfverberg (2004a), Silfverberg (2004b), Teodorescu et al. (2006), Tomov et al. (2009), Wittenberg (2005)
Sitophilus zeamais Motschulsky 1855	C	phyto-phagous (spe)	*Cryptogenic*	1927, DE	AD, AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES-CAN, FI, FR, GB, IT, IT-SAR, IT-SIC, PL, PT, PT-AZO, PT-MAD, RU, SE	J1	grain (op: cereal grain)	Balachowsky (1963), Dal Monte (1972), Essl and Rabitsch (2002), Haghebaert (1991), Lundberg (1995), Machado and Oromí (2000), Obretenchev et al. (1990), Tomov et al. (2009), Wittenberg (2005)
Erirhinidae								
Lissorhoptrus oryzophilus Kuschel 1952	A	phyto-phagous (rbw)	North America	2004, IT	IT	I1	*Oryza*, *Carex* (pp: Gramineae, Cyperaceae)	Caldara et al. (2004)
Stenopelmus rufinasus Gyllenhal 1835	A	phyto-phagous (lbw)	North America	1900, FR	BE, DE, ES, FR, GB, IE, IT, NL	C1, C2	*Azolla* (mp: *Azolla*)	Baars and Caffery (2008), Dana and Viva (2006), Fernandez Carrillo et al. (2005), Hill et al. (2005), Janson (1921)

Table 8.2.2. Characteristics of the Curculionoidea species alien *in* Europe. See Table 8.2.1 legend. Native range: „Mediterranean“ refers to southern Europe, North Africa and western Asia; „West Mediterranean“ refers to southern Europe and North Africa.

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Anthribidae						
Bruchela rufipes (Olivier 1790)	phytophagous (spe)	Europe	GB	I2	N/A (mp: *Reseda lutea*)	Hill et al. (2005), Morris (1990)
Apionidae						
Aspidapion (Aspidapion) radiolus (Marsham 1802)*	phytophagous (her)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	N/A	N/A (op: Malvaceae)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Catapion pubescens (W. Kirby 1811)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	N/A	N/A (mp: *Trifolium*)	Machado and Oromí (2000)
Eutrichapion (Cnemapion) vorax (Herbst 1797)*	phytophagous	Europe, West Mediterranean	ES-CAN	N/A	N/A (op: Fabaceae)	Machado and Oromí (2000)
Holotrichapion (Holotrichapion) ononis (W. Kirby 1808)*	phytophagous (spe)	Europe, Mediterranean, Asia	ES-CAN	N/A	N/A (mp: *Ononis*)	Machado and Oromí (2000)
Ischnopterapion (Ischnopterapion) plumbeomicans (Rosenhauer 1856)*	phytophagous (spe)	Mediterranean	ES-CAN	N/A	N/A (mp: *Lotus*)	Machado and Oromí (2000)
Ischnopterapion (Chlorapion) virens (Herbst 1797)*	phytophagous (her)	Europe, Mediterranean, Asia	ES-CAN	N/A	N/A (mp: *Trifolium*)	Machado and Oromí (2000)
Ixapion variegatum (Wencker 1864)	phytophagous (her)	Europe	GB	I2, H5	*Viscum album* (mp: *Viscum album*)	Duff (2008), Foster et al. (2001)
Kalcapion semivittatum (Gyllenhal 1833)*	phytophagous (her)	Europe, Mediterranean	ES-CAN, PT-AZO	N/A	N/A (mp: *Mercurialis*)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Brachyceridae						
Brachycerus plicatus Gyllenhal 1833*	phytophagous (her?)	Mediterranean	ES-CAN	N/A	N/A (op: Liliaceae?)	Machado and Oromí (2000)

Family / *subfamily* Species	Feeding habits	Native range	Invaded countries	Habitat	Hosts	References
Curculionidae						
Bagoinae						
Bagous exilis Jacquelin du Val 1854*	phytophagous	West Mediterranean	ES-CAN	B	N/A (coastal shrubs: *Frankenia*, Chenopodiaceae)	Machado and Oromí (2000)
Baridinae						
Melaleucus sellatus (Boheman 1844)*	phytophagous	West Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Melanobaris quadraticollis (Boheman 1836)*	phytophagous (her)	West Mediterranean	ES-CAN	I, J	N/A (op: Cruciferae)	Machado and Oromí (2000)
Ceutorhynchinae						
Ceutorhynchus assimilis (Paykull 1800)	phytophagous (spe)	Europe, West Mediterranean	PT-AZO	I, J	N/A (op: *Brassica*, Cruciferae)	Borges et al. (2005)
Micrelus ferrugatus (Perris 1847)*	phytophagous (spe)	West Mediterranean	ES-CAN	E	N/A (mp: *Erica*)	Machado and Oromí (2000)
Mogulones geographicus (Goeze 1777)	phytophagous (rbo)	Europe, West Mediterranean	PT-AZO	I, G	*Echium* (mp: *Echium*)	Borges et al. (2005)
Rhinoncus pericarpius (Linnaeus 1758)	phytophagous (rbo)	Europe, West Mediterranean, Asia	FÖ	E, I	N/A (mp: *Rumex*)	N/A
Cossoninae						
Brachytemnus porcatus (Germar 1824)	phytophagous (xyl)	Europe, West Mediterranean	PT-AZO	I2	N/A (op: Pinaceae)	Borges et al. (2005)
Pselactus spadix (Herbst 1795)	phytophagous (xyl)	Europe	PT-AZO	B, E	marine driftwood (pp: decaying wood)	Stüben (2003)
Pseudophloeophagus aeneopiceus (Boheman 1845)*	phytophagous (xyl)	Europe	PT-AZO	N/A	N/A (pp: decaying wood)	Base de dados da biodiversidade dos Açores
Rhopalomesites tardyi (Curtis 1825)	phytophagous (xyl)	Europe	PT-AZO	G	N/A (pp: dead wood)	Borges et al. (2005)
Cryptorhynchinae						
Dichromacalles (Dichromacalles) dromedarius (Boheman 1844)*	phytophagous (her?)	West Mediterranean	ES-CAN, PT-AZO	N/A	N/A (op: Compositae)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Curculioninae						
Mecinus circulatus (Marsham 1802)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	I, J	N/A (mp: *Plantago*)	Machado and Oromí (2000)
Mecinus longiusculus Boheman 1845*	phytophagous (her)	West Mediterranean	ES-CAN	I, J	N/A (op: Scrophulariaceae)	Machado and Oromí (2000)
Mecinus pascuorum (Gyllenhal 1813)	phytophagous (spe)	Europe, Mediterranean	ES-CAN, PT-AZO	I, J	*Plantago* (mp: *Plantago*)	Borges et al. (2005), Machado and Oromí (2000)
Pachytychius aridicola (Wollaston 1864)*	phytophagous (spe)	Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Philernus farinosus Gyllenhal 1835*	phytophagous	Europe, Asia	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Sibinia (Dichotychius) albosquamosa Pic 1904*	phytophagous (spe?)	Mediterranean	ES-CAN	N/A	*Limonium* (N/A)	Machado and Oromí (2000)
Sibinia (Dichotychius) planiuscula (Desbrochers 1873)*	phytophagous (spe?)	Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Sibinia (Sibinia) primita (Herbst 1795)*	phytophagous (spe)	Europe, West Mediterranean	ES-CAN	N/A	N/A (pp: Caryophyllaceae, Plumbaginaceae, Thymelaeaceae)	Machado and Oromí (2000)
Smicronyx albosquamosus Wollaston 1854*	phytophagous (her?)	West Mediterranean	ES-CAN, PT-MAD	N/A	N/A (N/A)	Hoffmann (1958), Machado and Oromí (2000)
Smicronyx brevicornis Solari 1952*	phytophagous (her)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Cuscuta*)	Machado and Oromí (2000)
Tychius (*Tychius*) *cuprifer* (Panzer 1799)	phytophagous (spe)	Europe, Mediterranean	PT-AZO	I1	N/A (mp: *Trifolium*)	Borges et al. (2005), Stüben (2003)
Tychius (*Tychius*) *picirostris* (Fabricius 1787)	phytophagous (spe)	Europe, Mediterranean, Asia	PT-AZO	I1, E	N/A (mp: *Trifolium*)	Borges et al. (2005)
Tychius (Tychius) stephensi Schonherr 1836*	phytophagous (spe)	Europe, Mediterranean, Asia	ES-CAN	N/A	N/A (mp: *Trifolium*)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tychius (Tychius) striatulus Gyllenhal 1836*	phytophagous (spe)	Mediterranean	ES-CAN	N/A	N/A (mp: *Ononis*)	Machado and Oromí (2000)
Cyclominae						
Gronops fasciatus Kuster 1851*	phytophagous	Mediterranean	ES-CAN	N/A	Opuntia (N/A)	Machado and Oromí (2000)
Entiminae						
Barynotus squamosus Germar 1824	phytophagous	Europe	FÖ	G	N/A (N/A)	N/A
Barypeithes (*Exomias*) *pellucidus* (Boheman 1834)	phytophagous (rbw?)	Europe	IS	I	*Medicago* (mp: *Medicago*)	Ólafsson (1991)
Cathormiocerus (*Cathormiocerus*) *curvipes* (Wollaston 1854)	phytophagous	Europe	PT-AZO	F5	*Pittosporum*? (N/A)	Stüben (2003)
Otiorhynchus (*Otiorhynchus*) *apenninus* Stierlin 1883	phytophagous (rbw)	Europe (Alps)	DK, GB, MT, NL, SE	I2	N/A (pp: *Acer*, *Camelia*, *Prunus*, *Rhododendron*)	Heijerman et al. (2003), Hill et al. (2005), Runge (2008)
Otiorhynchus (*Otiorhynchus*) *armadillo* (Rossi 1792)	phytophagous (rbw)	Europe (central)	GB, SE	I2, J4	N/A (*Alnus*)	Borisch (1997), Hill et al. (2005)
Otiorhynchus (*Nehrodistus*) *armatus* Boheman 1843	phytophagous (rbw)	Europe (southern)	SE	J100	*Fragaria*, *Vitis*, *Carduus*, *Rumex* (N/A)	Borisch (1997), Silfverberg (2004a), Silfverberg (2004b)
Otiorhynchus (*Otiorhynchus*) *aurifer* Boheman 1843	phytophagous (rbw)	Mediterranean	DK	N/A	N/A (N/A)	Runge (2008)
Otiorhynchus (*Pocodalemes*) *crataegi* Germar 1824	phytophagous (rbw)	Europe, Mediterranean	GB	I2	N/A (*Cyclamen*)	Hill et al. (2005)
Otiorhynchus (*Nehrodistus*) *corruptor* (Host 1789)	phytophagous (rbw)	Europe (southern)	DE, DK, FR, GB	I	*Pyrus*? (N/A)	Barclay (2001), Lucht (1985), Palm (1996), Valladares and Cocquempot (2008)
Otiorhynchus (*Arammichnus*) *cribricollis* Gyllenhal 1834	phytophagous (rbw)	West Mediterranean	ES-CAN, PT-AZO	I, J	N/A (mp: *Artemisia*)	Borges et al. (2005), Machado and Oromí (2000), Stüben (2003)
Otiorhynchus (*Arammichnus*) *dieckmanni* Magnano 1979	phytophagous (rbw)	Europe (western)	DK, SE	G, I2	N/A (N/A)	Borisch (1997), Runge (2008), Silfverberg (2004a), Silfverberg (2004b)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Otiorhynchus (*Padilehus*) *pinastri* (Herbst 1795)	phytophagous (rbw)	Europe (eastern)	CH	J	*Vincetoxicum* (N/A)	Germann (2004)
Otiorhynchus (Zustalestus) rugosostriatus (Goeze 1777)*	phytophagous (rbw)	Europe, West Mediterranean	PT-AZO	N/A	N/A (pp: *Rumex*, *Dactylis*, *Trifolium*...)	Base de dados da biodiversidade dos Açores
Otiorhynchus (*Metopiorrhynchus*) *singularis* (Linnaeus 1767)	phytophagous (rbw)	Europe	FÖ, IS	I2	N/A (N/A)	Ólafsson (1991)
Otiorhynchus (*Dorymerus*) *sulcatus* (Fabricius 1775)	phytophagous (rbw)	Europe	PT-AZO	F5	*Pittosporum*? (pp: *Vitis*...)	Borges et al. (2005), Stüben (2003)
Philopedon plagiatum (Schaller 1783)	phytophagous (rbw?)	Europe, West Mediterranean	PT-AZO	I,G	N/A (*Ammophila*)	Borges et al. (2005)
Psallidium (*Psallidium*) *maxillosum* (Fabricius 1792)	phytophagous	Europe (southcentral, southeastern)	SE	I1	N/A (N/A)	Lundberg (2006)
Rhytideres (Rhytideres) plicatus (Olivier 1790)*	phytophagous (rbw)	Mediterranean	ES-CAN	N/A	N/A (pp: Resedaceae, Cruciferae)	Machado and Oromí (2000)
Sitona (Charagmus) cachectus Gyllenhal 1834*	phytophagous (rbw)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Astragalus*)	Machado and Oromí (2000)
Sitona (*Sitona*) *cinnamomeus* Allard 1863	phytophagous (rbw)	Mediterranean	PT-AZO	I, G	N/A (op: *Lotus*, *Trifolium*, Fabaceae)	Borges et al. (2005)
Sitona (*Sitona*) *discoideus* Gyllenhal 1834	phytophagous (rbw)	Mediterranean	ES-CAN, PT-AZO	I, G	N/A (mp: *Medicago*)	Borges et al. (2005), Machado and Oromí (2000)
Sitona (Charagmus) gressorius (Fabricius 1792)*	phytophagous (rbw)	Mediterranean, Asia	ES-CAN, PT-AZO	N/A	N/A (mp: *Lupinus*)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Sitona (*Sitona*) *lepidus* Gyllenhal 1834	phytophagous (rbw)	Europe, Mediterranean	PT-AZO	I, J	N/A (op: *Lotus*, *Trifolium*, Fabaceae)	Borges et al. (2005)
Sitona (Sitona) lineatus (Linnaeus 1758)*	phytophagous (rbw)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	I, J	N/A (op: Fabaceae)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Sitona (Sitona) macularius (Marsham 1802)*	phytophagous (rbw)	Europe, Mediterranean, Asia	ES-CAN	I, J	N/A (mp: *Trifolium*)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sitona (Sitona) ocellatus Kuster 1849*	phytophagous (rbw)	Mediterranean	ES-CAN	N/A	N/A (Fabaceae?)	Machado and Oromí (2000)
Sitona (*Sitona*) *puberulus* Reitter 1903	phytophagous (rbw)	Mediterranean	ES-CAN, PT-AZO, PT-MAD	I, J	N/A (mp: *Lotus*)	Borges et al. (2005), Hoffmann (1950), Machado and Oromí (2000), Stüben (2003)
Sitona (*Sitona*) *puncticollis* Stephens 1831	phytophagous (rbw)	Europe, Mediterranean, Asia	FÖ, PT-AZO	I	N/A (op: *Trifolium*, *Melilotus*?)	Borges et al. (2005)
Sitona (Charagmus) variegatus Fåhraeus 1840*	phytophagous (rbw)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Astragalus*)	Machado and Oromí (2000)
Strophosoma (*Strophosoma*) *melanogrammum melanogrammum* (Forster 1771)	phytophagous (rbw?)	Europe	PT-AZO	G, I2	N/A (pp: *Rumex*, *Aira*...)	Borges et al. (2005)
Trachyphloeus (Trachyphloeus) angustisetulus Hansen 1915*	phytophagous (rbw?)	Europe	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Trachyphloeus (Trachyphloeus) laticollis Boheman 1843*	phytophagous (rbw?)	Mediterranean	ES-CAN	N/A	*Mercurialis*, *Bidens* (N/A)	Machado and Oromí (2000)
Trachyphloeus (Trachyphloeus) spinimanus Germar 1824*	phytophagous (rbw)	Europe, Asia	ES-CAN	N/A	N/A (mp: *Cynodon*)	Machado and Oromí (2000)
Hyperinae						
Coniatus (Coniatus) tamarisci (Fabricius 1787)*	phytophagous	Mediterranean	ES-CAN	N/A	N/A (mp: *Tamarix*)	Machado and Oromí (2000)
Donus (*Antidonus*) *lunatus* (Wollaston 1854)*	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN	E	N/A (op: Geraniaceae)	Machado and Oromí (2000)
Hypera (Hypera) melancholica (Fabricius 1792)*	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN	I, J	N/A (op: *Medicago*, *Trifolium*)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hypera (Hypera) nigrirostris (Fabricius 1775)*	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN	E, J	N/A (op: *Ononis*, *Trifolium*)	Machado and Oromí (2000)
Hypera (Hypera) ononidis (Chevrolat 1863)*	phytophagous (lbw)	Europe, West Mediterranean	ES-CAN	E	N/A (mp: *Ononis*)	Machado and Oromí (2000)
Hypera (*Hypera*) *postica* (Gyllenhal 1813)	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	I, J	N/A (op: Fabaceae)	Borges et al. (2005), Machado and Oromí (2000)
Lixinae						
Coniocleonus excoriatus (Gyllenhal 1834)*	phytophagous	Europe, Mediterranean	ES-CAN, PT-AZO	N/A	N/A (N/A)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Coniocleonus variolosus (Wollaston 1864)*	phytophagous	West Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Conorhynchus (Pycnodactylus) brevirostris (Gyllenhal 1834)*	phytophagous (rbo)	Mediterranean, Africa	ES-CAN	B	N/A (op: Chenopodiaceae)	Machado and Oromí (2000)
Conorhynchus (Pycnodactylus) conicirostris (Olivier 1807)*	phytophagous	Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Lixus (Compsolixus) anguinus (Linnaeus 1767)*	phytophagous (her)	West Mediterranean	ES-CAN	E?	N/A (op: *Cheiranthus*, *Sinapis*)	Machado and Oromí (2000)
Lixus (Eulixus) brevirostris Boheman 1835*	phytophagous (her)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Atriplex*)	Machado and Oromí (2000)
Lixus (Epimeces) filiformis (Fabricius 1781)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	I, J	N/A (mp: *Carduus*)	Machado and Oromí (2000)
Lixus (Compsolixus) juncii Boheman 1835*	phytophagous (her)	Mediterranean, Asia	ES-CAN	N/A	N/A (op: Chenopodiaceae)	Machado and Oromí (2000)
Lixus (Dilixellus) linearis Olivier 1807*	phytophagous (her)	Europe, Mediterranean	ES-CAN	I, J	N/A (mp: *Rumex*)	Machado and Oromí (2000)
Lixus (Dilixellus) pulverulentus (Scopoli 1763)*	phytophagous (her)	Europe, Asia, North Africa	ES-CAN	N/A	N/A (op: Malvaceae, Fabaceae)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Rhinocyllus conicus (Froelich 1792)	phytophagous (spe)	Europe, Mediterranean	LT, LV, SE	E, I	N/A (op: *Carduus*, *Cirsium*, *Galactites*, *Cynara*...)	Gillerfors (1988), Lundberg (2006)
Mesoptiliinae						
Magdalis (*Magdalis*) *memnonia* (Gyllenhal 1837)	phytophagous (her)	Europe, Mediterranean, Asia	GB	G3	*Pinus* (mp: *Pinus*)	Hill et al. (2005)
Molytinae						
Anisorhynchus hespericus Desbrochers 1875*	phytophagous	Europe (southwestern)	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Ita crassirostris Tournier 1878*	phytophagous	Europe (southern)	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Liparus (*Liparus*) *glabrirostris* Küster 1849	phytophagous	Europe (Alps)	DK	G	N/A (mp: *Heracleum*)	Hansen (1996)
Pissodes (Pissodes) castaneus (De Geer 1775)*	phytophagous (phl)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	G	N/A (mp: *Pinus*)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Scolytinae						
Chaetoptelius vestitus (Mulsant & Rey 1860)*	phytophagous (phl)	Mediterranean, Asia	ES-CAN	G1, I2	*Laurus* (pp: *Pistacia*, *Cotinus*, *Olea*, *Smilax*)	Schedl et al. (1959)
Crypturgus subcribrosus Eggers 1933	phytophagous (phl)	Europe (central, eastern)	GB	G3	*Picea* (op: *Pinus*, *Abies*, *Picea*)	Alexander (2002)
Dendroctonus micans (Kugelann 1794)	phytophagous (phl)	Europe, Asia	GB	G3	*Picea* (mp: *Picea*)	Alexander (2002), Hill et al. (2005)
Dryocoetes villosus (Fabricius 1792)*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, PT-MAD	G1	*Laurus* (pp: *Laurus*, *Alnus*)	Schedl (1963), Schedl et al. (1959)
Hylastes angustatus (Herbst 1793)	phytophagous (phl)	Europe (southern, central), Asia	GB	G3	*Pinus* (mp: *Pinus*)	Alexander (2002)
Hylastes ater (Paykull 1800)	phytophagous (phl)	Europe, Asia	GB, PT-AZO	G3, I2	*Pinus* (mp: *Pinus*)	Alexander (2002), Bright (1987)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hylastes attenuatus Erichson 1836	phytophagous (phl)	Europe, Mediterranean, Asia	GB, PT-AZO, PT-MAD	G3	*Pinus* (mp: *Pinus*)	Alexander (2002), Bright (1987), Mandelshtam et al. (2006)
Hylastes cunicularius Erichson 1836	phytophagous (phl)	Europe, Asia	GB	G3	*Picea* (mp: *Picea*)	Alexander (2002)
Hylastes linearis Erichson 1836*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, PT-MAD	G3	*Pinus* (mp: *Pinus*)	Schedl (1963), Schedl et al. (1959)
Hylastinus obscurus (Marsham 1802)*	phytophagous (phl, rbo)	Europe, West Mediterranean	ES-CAN, PT-MAD	F5, F7	*Cytisus*, *Laurus*, *Castanea* (op: *Trifolium*, Fabaceae);	Schedl (1963), Schedl et al. (1959)
Hylurgops palliatus (Gyllenhal 1813)	phytophagous (phl)	Europe, Mediterranean, Asia	GB	G3	N/A (op: Pinaceae)	Alexander (2002)
Hylurgus ligniperda (Fabricius 1787)*	phytophagous (phl)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO, PT-MAD	G3	*Pinus* (mp: *Pinus*)	Bright (1987), Schedl (1963), Schedl et al. (1959)
Hypoborus ficus Erichson 1836*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, PT-AZO, PT-MAD	I2	*Echium*, *Ficus* (mp: *Ficus*)	Bright (1987), Schedl (1963), Schedl et al. (1959)
Ips cembrae (Heer 1836)	phytophagous (phl)	Europe (central)	DK, GB, NL	G3	*Larix* (op: *Larix*, *Pinus cembra*)	EPPO (2005), Hill et al. (2005), Stauffer et al. (2001)
Ips duplicatus (Sahlberg 1836)	phytophagous (phl)	Europe (northeastern, Russia)	AT, BE, SK	G3	*Picea abies* (mp: *Picea*)	Essl and Rabitsch (2002), OPIE (2002), Piel et al. (2006)
Orthotomicus erosus (Wollaston 1857)*	phytophagous (phl)	Europe, Mediterranean, Asia	PT-MAD	G3	*Pinus* (mp: *Pinus*)	Schedl (1963)
Phloeosinus armatus Reitter 1887	phytophagous (phl)	Mediterranean (eastern)	IT	FA, G5	*Cupressus* (op: Cupressaceae)	Covassi (1991)
Phloeosinus aubei (Perris 1855)[9]	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, NL	G3	*Juniperus* (op: Cupressaceae)	Moraal (2006), Oromí and García (1995)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Phloeosinus thujae (Perris 1855)	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, GB	FA, G5	*Juniperus* (op: Cupressaceae)	Alexander (2002), Machado and Oromí (2000)
Phloeotribus caucasicus Reitter 1891	phytophagous (phl)	Europe (eastern), Asia	AT, CZ, FR	FA, G5	*Fraxinus* (mp: *Fraxinus*)	Bouget and Noblecourt (2005), Essl and Rabitsch (2002), Schott and Callot (1994)
Phloeotribus cristatus (Fauvel 1889)*	phytophagous (phl)	West Mediterranean	ES-CAN	F5, F7	N/A: Fabaceae? (op: Fabaceae)	Machado and Oromí (2000)
Phloeotribus rhododactylus (Marsham 1802)*	phytophagous (phl)	Europe, West Mediterranean	PT-MAD	F5, F7	*Cytisus* (op: Fabaceae)	Schedl (1963)
Phloeotribus scarabaeoides (Bernard 1788)*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN	I2	N/A: Oleaceae? (op: Oleaceae)	Machado and Oromí (2000)
Pityophthorus traegardhi Spessivtseff 1921	phytophagous (phl)	Europe (northern), Asia	AT	G3	*Picea* (mp: *Picea*)	Holzschuh (1994)
Polygraphus poligraphus (Linnaeus 1758)	phytophagous (phl)	Europe (central, northern, eastern)	GB	G3	N/A (op: Pinaceae)	Alexander (2002)
Pteleobius kraatzii (Eichhoff 1864)*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN	I2, G1, G5, FA	N/A: *Ulmus*? (mp: *Ulmus*)	Pfeffer (1995)
Scolytus amygdali Guérin-Méneville 1847*	phytophagous (phl)	Europe, Mediterranean, Asia	ES-CAN	I2	*Prunus* (op: Rosaceae trees)	Israelson (1969)
Scolytus laevis Chapuis 1869	phytophagous (phl)	Europe	GB	G1, G5, I2	*Ulmus* (mp: *Ulmus*)	Hill et al. (2005)
Scolytus pygmaeus (Fabricius 1787)	phytophagous (phl)	Europe	GB	G1, I2, FA, FB	*Ulmus* (mp: *Ulmus*)	Hill et al. (2005)
Scolytus rugulosus (Muller 1818)*	phytophagous (phl)	Europe, Mediterranean, Asia	PT-AZO	I2	N/A (op: Rosaceae trees)	Bright (1987)

[9] This species was incorrectly reported from the Canary Islands (Oromí and García 1995) as *P. gillerforsi* Bright, an Azores endemic. Specimens so identified have been examined by Kirkendall, and they belong to the common Mediterranean species *P. aubei*.

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tomicus destruens (Wollaston 1865)[10]	phytophagous (phl)	Europe, Asia	PT-MAD	G3, I2	*Pinus* (mp: *Pinus*)	Schedl (1963)
Xyleborinus saxesenii (Ratzeburg 1837)[11]	phytophagous (xmp)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO, PT-MAD	I2	*Laurus*, *Pinus*, *Castanea* (pp: broadleaves, conifers)	Bright (1987), Schedl et al. (1959)
Dryophthoridae						
Sphenophorus meridionalis Gyllenhal 1838	phytophagous (rbo?)	West Mediterranean	ES-CAN	E6	N/A (N/A)	Machado and Oromí (2000)
Erirhinidae						
Procas armillatus (Fabricius 1801)*	phytophagous	Europe, Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Nanophyidae						
Dieckmanniellus nitidulus (Gyllenhal 1838)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	N/A	N/A (mp: *Lythrum*)	Machado and Oromí (2000)
Nanodiscus transversus (Aube 1850)	phytophagous (spe)	West Mediterranean	ES-CAN	N/A	N/A (op: *Juniperus*, *Cupressus*)	Machado and Oromí (2000)
Nemonychidae						
Cimberis attelaboides (Fabricius 1787)	phytophagous (spe)	Europe, Mediterranean, Asia	GB	G3	*Pinus sylvestris* (mp: *Pinus sylvestris*)	Duff (2008)

[10] Early records from Madeira refer to *T. piniperda*, but specimens collected by Kirkendall in 1999 are *T. destruens*; as the two species had been mixed up for a long time we think all records correspond to *T. destruens*

[11] This species has been improperly recorded in the Canary Islands as *Xyleborus xylographus*. *Xyleborus xylographus* (Say 1826), an oak specialist from the eastern United States, does not occur in any recent collections from the archipelago (or elsewhere in Europe), whereas *X. saxesenii* does (Kirkendall, unpublished data). The presence of *X. xylographus* on all Canary Islands species lists (Schedl et al. 1959, Oromi and Garcia 1995, Machado and Oromi 2000, Izquierdo et al. 2004), and the absence of *X. saxesenii*, seems to stem from an early mistaken treatment of *X. saxesenii* as a junior synonym of *X. xylographus* (Schedl 1970). To verify this, Kirkendall located one specimen recently determined as *X. Xylographus* (Oromi and Garcia 1995), and confirmed that it is *X. saxesenii*.

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Leaf and Seed Beetles (Coleoptera, Chrysomelidae) Chapter 8.3

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Abstract
The inventory of the leaf and seed beetles alien to Europe revealed a total of 25 species of which 14 seed beetles (bruchids) and 11 leaf beetles mostly belonging to the subfamilies Alticinae and Chrysomelinae. At present, aliens account for 9.4% of the total fauna of seed beetles in Europe whereas this percentage is less than 1% for leaf beetles. Whilst seed beetles dominated the introductions in Europe until 1950, there has been an exponential increase in the rate of arrival of leaf beetles since then. New leaf beetles arrived at an average rate of 0.6 species per year during the period 2000–2009. Most alien species originated from Asia but this pattern is mainly due to seed beetles of which a half are of Asian origin whereas leaf beetles predominantly originated from North America (36.4%). Unlike other insect groups, a large number of alien species have colonized most of Europe. All but one species have been introduced accidentally with either the trade of beans or as contaminants of vegetal crops or stowaway. Most aliens presently concentrate in man-made habitats but little affect natural habitats (<6%). Highly negative economic impacts have been recorded on stored pulses of legumes and crops but very little is known about possible ecological impact.

Keywords
Coleoptera, Chrysomelidae, Bruchidae, seed beetle, leaf beetle, bioinvasion, alien, Europe, translocation, introduction

8.3.1 Introduction

The family Chrysomelidae is one of the largest Coleopteran families, including ca. 37 000 described species in the world and perhaps the same number as yet undescribed (Jolivet and Verma 2002). Bruchidae, or seed beetles, is a relatively small family. Kingsolver (2004), referring to the most recent world catalogue, mentions 1,346 valid bruchid species. Although there are good arguments to treat Bruchidae as a subfamily of Chrysomelidae and raise some leaf beetle subfamilies to family rank (Reid 1995), this is still not common practice among leaf beetle researchers. We treat Bruchidae and Chrysomelidae in this contribution as families, merely for practical reasons. According to *Fauna Europaea*, the fauna presently observed in Europe includes 1532 leaf beetles and 145 seed beetles.

Except for important agricultural pests such as the Colorado potato beetle, *Leptinotarsa decemlineata*, and more recently, the western corn rootworm, *Diabrotica virgifera virgifera*, little was known about introductions of alien leaf beetles until Beenen (2006) revealed that 126 species have been translocated at least once from one continent to another. More information on alien seed beetles has been available in the literature mainly because of their potential impact on stored products (Southgate 1979). In the present work, we will show that 25 non-native species of leaf and seed beetles of which one is of unknown origin (cryptogenic) have already established in Europe (Table 8.3.1). Thus, aliens still represent only a very small proportion (1.5%) of the total fauna of leaf and seed beetles in Europe. By comparison, approximately 71 alien leaf beetle species have been recorded from North America (Beenen 2006, Beenen, unpubl.).

Within Europe, changes in the distribution of native leaf beetles have also been noticed which can be partly associated either to human activity or to natural trends such as delayed post-glacial expansion and global warming. For example, the recent northwards expansion of a flea beetle, *Longitarsus dorsalis,* seems to result from both the introduction of a rapidly expanding invasive plant originating from South Africa, *Senecio inaequidens* DC., on which *L. dorsalis* thrives (Beenen 1992), and from increasing temperatures during the past years. However, the role of human activity is often difficult to ascertain in such observed range expansions of native species. We will essentially consider the species alien *to* Europe, a summary of the species alien *in* Europe (Table 8.3.2) and will present their characteristics at the end of the chapter.

8.3.2 Taxonomy

A total of 25 alien species of which 14 seed beetles and 11 leaf beetles have been recorded as established in Europe (Table 8.3.1). Thus, bruchids represent more than a half (56.0%) of the alien species whereas they account for only 8.1% of the native fauna of seed and leaf beetles (Figure 8.3.1). This arrival of alien seed beetles has

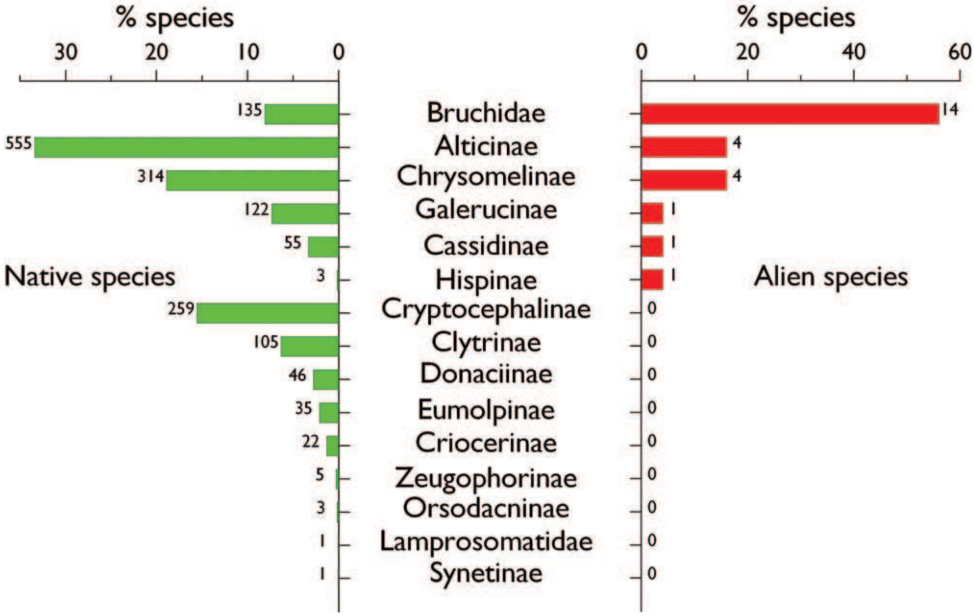

Figure 8.3.1. Comparison of the relative importance of the subfamilies of Chrysomelidae and Bruchidae in the alien and native entomofauna in Europe. Subfamilies are presented in a decreasing order based on the number of alien species. The number right to the bar indicates the number of species per family.

significantly modified the composition of the total fauna of seed beetles observed in Europe, where aliens account for 9.4% at present. The pattern is rather different for Chrysomelidae. Although this family includes 13 subfamilies in Europe the alien entomofauna is only distributed among five of these subfamilies. Large differences are observed in the contribution of each subfamily without any apparent correlation to its numerical importance in the native fauna. The recent arrival in France of an alien palm hispine beetle, *Pistosia dactylifera* (Drescher and Martinez 2005), largely modified the composition of the Hispinae subfamily which includes only three native species (Fauna Europaea 2009). However, aliens represent much less so for the two major subfamilies of leaf beetles, Alticinae flea beetles (four species- 0.7% of the total) and Chrysomelinae (four species- 1.3% of the total). Other alien species include one skeletonizing leaf beetle (Galerucinae) and one tortoise leaf beetle (Cassidinae). The same subfamily pattern is observed for translocations of leaf beetles at world level but Beenen (2006) also noticed other species belonging to Hispinae (e.g. *Brontispa* palm leaf beetles) and Criocerinae. It is noticeable that representatives from some important subfamilies such as Cryptocephalinae and Donaciinae have never been introduced, or never established at least.

Leaf beetles and seed beetles largely differ in biological traits that may be involved in the relative success of seed beetle invaders compared to other groups. Seed beetles have several ways of egg-laying. Most species deposit their eggs on mature pods of legumes (Fabaceae), the eggs being cemented to the pod or dropped in a self- made hole in the pod wall. Other species lay eggs on mature seeds that are still attached to the inside of a partly opened pod. A third group of species oviposit on mature seeds that have fallen to the ground from a fully dehisced pod. However, some species such as *Acantoscelides obtectus* use different life history strategies. Early in the season in this species, oviposition occurs on green pods of *Phaseolus*, while later in the season, the eggs are deposited on mature seeds that have fallen to the ground. These biological features make *A. obtectus* fully capable of completing cycle after cycle on naked seeds in storage (Kingsolver 2004). The larvae of seed beetles entirely develop within the seeds until pupation and their presence cannot be recognized before adult emergence, unless the seed is X-rayed.

In contrast, leaf beetles show a large variety of reproductive traits. Many Galerucinae (e.g., *Diabrotica* species) and Alticinae larvae (e.g., *Epitrix* species) develop in or at the roots of plants and adults feed from leaves of a specific host plant or a wide variety of plant species. Other Chrysomelidae feed both as larva and adult externally on leaves of their host plants. Although practically no plant species is free of leaf beetles, most leaf beetles need fresh plant products in all or at least in the adult stage. Stored dry plant products are not suitable for leaf beetles to complete their life cycle.

8.3.3 Temporal trends

Chrysomelids probably began to be introduced thousands of years ago. It is likely that leaf beetles associated with crops have taken the same route as herbs associated with cereals which are supposed to have entered Europe from the Near East (Pinhasi et al. 2005). Beenen (2006) argued that the combination of *Buglossoides arvensis* (L.) Johnston and *Longitarsus fuscoaeneus* Redtenbacher 1849 might have taken the route from southwest Asia where they spread with agriculture to large parts of the temperate parts of the Northern hemisphere. Thus, a number of species which are at present considered as native may indeed be originally alien. Bruchidae must have infested pulses grown by man since the dawn of agriculture. Southgate (1979) also mentioned infestations of lentils from the Egyptian Ptolemaic period (305 BC – 30 BC). Relatively little is known of these ancient introductions. More recent ones are much better documented as in the case of the potato Colorado beetle (*Leptinotarsa decemlineata*) (see factsheet 14.10).

From a global point of view, new records of alien species in Europe were relatively important during the 2nd half of the 19th century, due to seed beetle species. The most important being *Acanthoscelides obtectus*, *Callosobruchus chinensis* and *C. maculatus*. However, these species may have been introduced well before their first record. Since ca. 1900, the rate of seed and leaf beetle introductions severely decreased until 1975 when it began to increase again with globalization, essentially through the arrival of leaf beetles. The last seven years since 2000 corresponded to an acceleration of introductions, with an average of 0.8 new species of Chrysomelidae per year, again mostly leaf beetles (Figure 8.3.2)

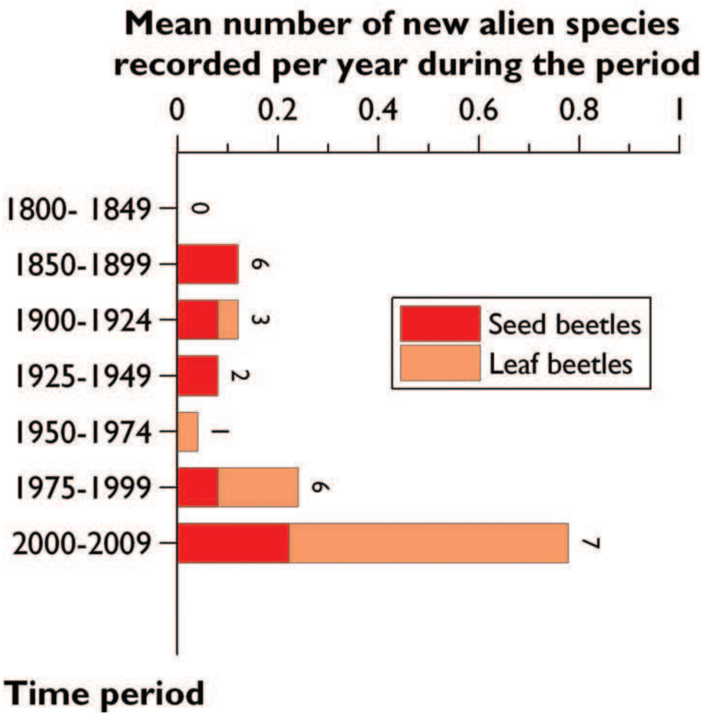

Figure 8.3.2. Temporal changes in the mean number of new records per year of seed and leaf beetle species alien *to* Europe from 1800 to 2009. The number right to the bar indicates the total number of seed and leaf beetle species recorded per time period.

8.3.4 Biogeographic patterns

Asia supplied the major proportion of the alien seed and leaf beetles that have established in Europe (Figure 8.3.3). However, this pattern is mainly due to seed beetles of which a half are of Asian origin whereas leaf beetles predominantly originated from North America (36.4%). No seed and leaf beetle species of Australasian origin have yet established in Europe.

Alien species are not evenly distributed in Europe, and leaf and seed beetles do not show the same pattern of expansion. Half of the alien seed beetles have colonized more than ten countries with four of them present in more than 50 countries and the main islands of Europe. In contrast, 63.6% of the alien leaf beetles have not yet spread out of the country where they have been initially introduced. Only two species, *Leptinotarsa decemlineata* and *Diabrotica virgifera*, are presently encountered in 38 and 20 countries respectively (EPPO 2009, Gödöllo University 2004, Grapputo et al. 2005, Purdue University 2008) (see maps in the spreadsheets 8 and 10). Owing to climate change, *L. decemlineata* may extend its range to Finland (Valosaari et al. 2008).

Alien seed and leaf beetles appear to be concentrated in southern Europe with 18 species observed in mainland Italy and more than 10 species in continental France

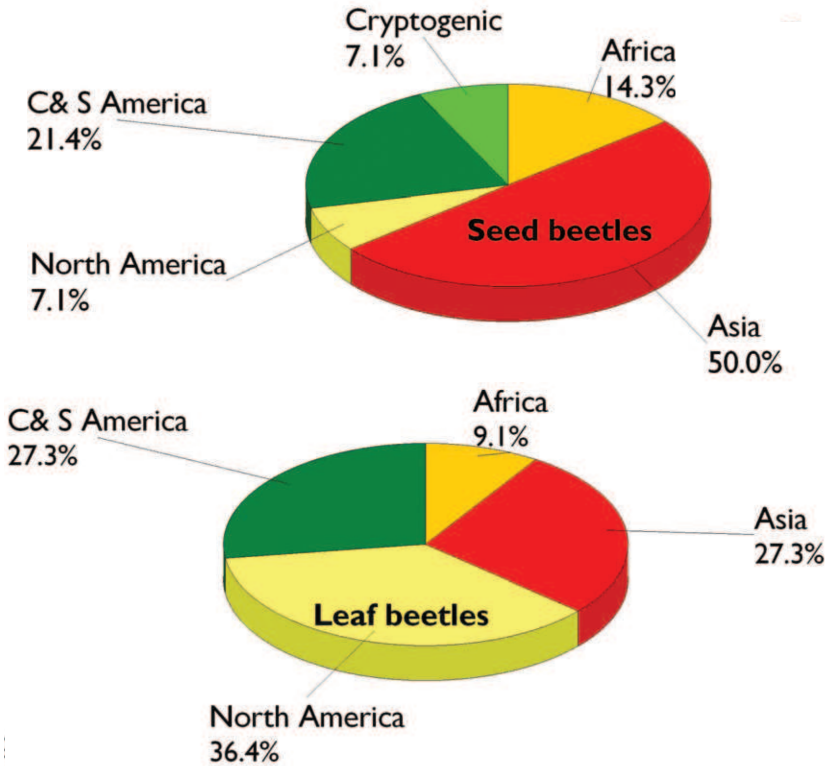

Figure 8.3.3. Comparative origin of seed and leaf beetle species alien *to* Europe

and mainland Greece. Central Europe usually hosts less than 10 species except Czech Republic (11 species), whereas aliens have been little recorded in Northern Europe (Figure 8.3.4).

8.3.5 Main pathways and vectors to Europe

All alien species of seed and leaf beetle except one (i.e., 95.7%) have been introduced accidentally to Europe. Unlike North America and South Africa, where a number of alien species were released for biological control of weeds (Beenen 2006), only the ragweed leaf beetle, *Zygogramma suturalis*, has been intentionally introduced from North America for the biological control of common ragweed, *Ambrosia artemisifolia* L., since 1978 in Russia (Reznik et al. 2004) and several countries of southeastern Europe, and subsequently established in the wild especially in the Caucasus (Kovalev 2004). A flea beetle native of Continental Europe, *Altica carduorum* (Guérin- Méneville), has also been introduced in Britain and Wales in 1969–1970 to control creeping thistles, *Cirsium arvense* (L.) Scop. but none apparently established (Baker et al. 1972, Cox 2007). Although it is difficult to ascertain the exact pathway of introduction for most of the

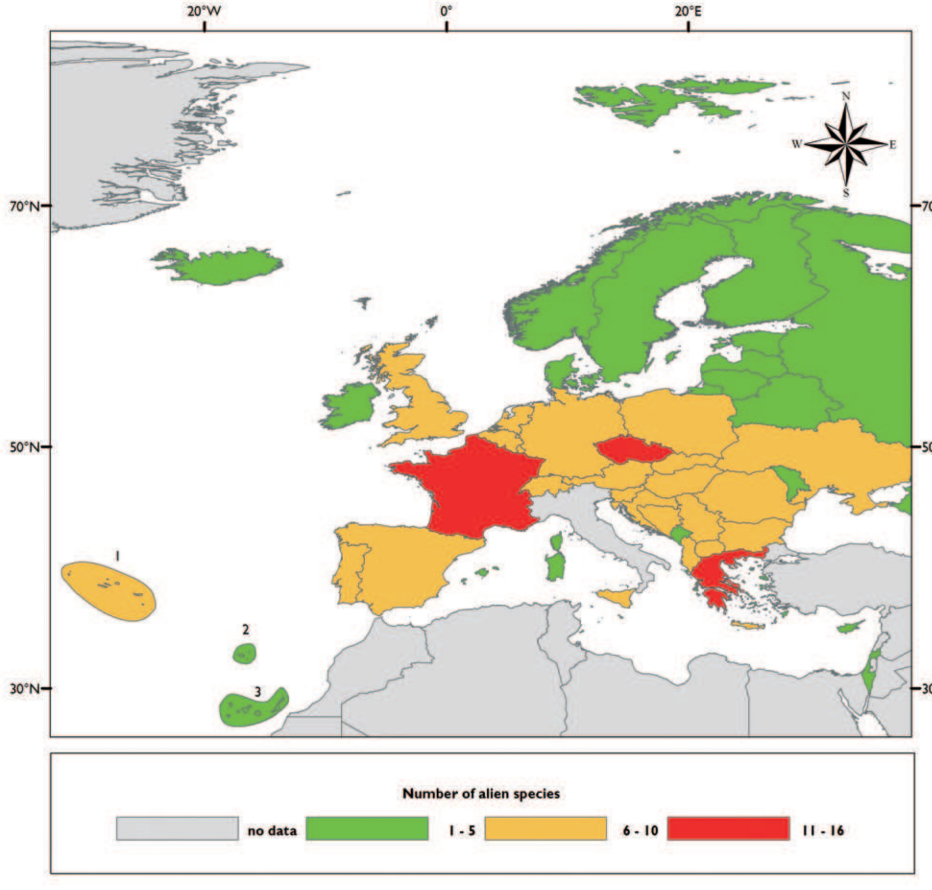

Figure 8.3.4. Colonization of continental European countries and main European islands by seed and leaf beetle species alien *to* Europe.

other species introduced accidentally, the general behaviour of chrysomelids suggests that most introductions are related to trade of plants and stored products, although some may have arrived as stowaways in all forms of packaging and transport, or even as wind-borne organisms.

The world trade of beans for agricultural purposes is probably responsible for the nowadays wide distribution in Europe of most alien species of seed beetles, such as *Acanthoscelides obtectus*, *Bruchus* species *Callosobruchus* species and *Zabrotes subfasciatus* (Figure 8.3.8) which develop in legume seeds of the subfamily Papilionoideae (*Phaseolus, Lathyrus, Pisum, Vicia)* (Böhme 2001, Kingsolver 2004). However, the arrival of other seed beetles of the genera *Bruchidius*, *Caryedon*, *Megabruchidius* and *Mimosestes* seems to be more related to the trade in legume tree seeds of Mimosoideae (*Albizzia, Acacia*) and Caesalpinoideae (*Cassia, Cercis, Tamarindus*) used as ornamentals in parks and gardens. *Megabruchidius tonkineus* was at first suspected to have been introduced from Vietnam to Germany with white beans (Wendt 1980) but it was later found to be associated with pods of honey locust trees, *Gleditsia triacanthos* L. (Papilionoideae), and not capable of complete development in beans (Guillemaud et al. 2010). Similarly, *Acanthoscelides pallidipennis* was probably introduced with seeds of false indigo bush (*Amorpha fructicosa* L., Papilionoideae) (Tuda et al. 2006) and *Bruchidius siliquastri* with these of redbuds (*Cercis*; Caesalpinoideae) from China (Kergoat et al. 2007). Seeds imported for ornamental purposes may also serve as the vector of seed beetles. *Specularius impressithorax* (Pic) sustained several generations indoors in the Netherlands after having been introduced from South Africa along with seeds of *Erythrina* (Papilionoideae) used for decoration, but did not eventually establish (Heetman and Beenen 2008) (Figure 8.3.7).

Most alien leaf beetles are associated with vegetable crops (Solanaceae, Brassicaceae, Gramineae including maize). With both larvae and adults feeding on foliage, these species probably entered Europe as plant contaminants (eggs, larvae) or crop contaminants (adults). The Colorado potato beetle has frequently been intercepted with potato plants and tubers, but also in all forms of packaging and transport. For example, it usually arrived to Great Britain with commercial freight among vegetable crops such as lettuce, *Lactuca sativa* L., or on ships, aircraft or private cars traveling from the continent (Cox 2007). Indeed, fresh vegetables grown on land harbouring overwintering beetles are common means of beetle transport in international trade (Bartlett 1980). The African tortoise beetle *Aspidimorpha fabricii* (= *A. cincta* Fabricius) was believed to be imported in Italy as a contaminant of bananas in the late 1950s but it became a problem in cultures of *Beta vulgaris* L. (Zangheri 1960). A hispine palm leaf beetle, *Pistosia dactyliferae* was also probably introduced as a contaminant of palms imported for ornamental purposes (Drescher and Martinez 2005).

The means of introduction appears different when larvae are root-feeding as in *Diabrotica* and *Epitrix* species. Unless soil infested with larvae has been imported with host plants, which is usually prohibited, these species probably travel as stowaways. The western corn rootworm, *Diabrotica virgifera virgifera*, proved to have been translocated from North America to Europe at least three times in aircraft laden with goods and materials, but probably not with maize plants (Ciosi et al. 2008, Miller et al. 2005). The outbreaks in Northwestern Italy and Central Europe probably resulted from introductions of individuals originating in northern USA (Delaware) (Guillemaud et al. 2010).

However, another pest species related to tobacco, *Epitrix hirtipennis*, is assumed to have arrived in Europe as aerial plankton with easterly trade winds blowing from the New World to Europe (Döberl 1994b). Similarly, Jolivet (2001) reported the translocation of the Sweet potato flea beetle, *Chaetocnema confinis* Crotch, from the USA to several tropical destinations by hurricanes. Adults of Colorado potato beetle are also assumed to be capable of migrating across the Channel although this beetle does not fly strongly (Cox 2007) or from Russia (the St Petersburg region) to Finland (Grapputo et al. 2005).

The collection and trade of orchids for greenhouses has also resulted in the arrival of several species which caused severe damage without persisting such as a flea beetle, *Acrocrypta purpurea* Baly, a species from Southeast Asia which was accidentally introduced with plant collections into a greenhouse of Leiden University in the Netherlands (Döberl 1994a). Likewise, larvae of a criocerine species, the yellow orchid beetle *Lema pectoralis* Baly, were imported to the Netherlands with an orchid collected in 1988 in Thailand (Beenen, unpubl.). Originating of the Peninsula Malaysia and Singapore (Mohamedsaid 2004), *L. pectoralis* is a major pest ('orchid lema') of orchid cultures, particularly *Vanda* and *Dendrobium*, in the Philippines (de la Cruz 2003).

Pathways within Europe are a source of particular concern because of the waiver of formerly routine phytosanitary inspections on goods transported within the European Union. Thus, alien species once introduced into one European country along with alien plants or seeds, can freely move to other European countries. Spread may combine long-distance, human-mediated dispersal and natural dispersal by adult flight, as it is the case for *Leptinotarsa decemlineata* (Grapputo et al. 2005). Another significant example is the present northwards expansion of a species alien in Europe, *Chrysolina americana*. This leaf beetle originates from the Mediterranean Basin where it is associated to *Rosmarinus* and *Lavendula.* Because both plants are popular garden plants throughout Europe, *C. americana* has been translocated outside its native range along with its host plants, e.g. to the Netherlands along with potted *Lavendula* plants imported from Italy (Beenen, unpubl.). Once introduced, this species, which has good flight capacities, disperses naturally by flight.

8.3.6 Most invaded ecosystems and habitats

All alien Chrysomelidae are phytophagous. As expected from the numerical importance of Bruchidae within aliens, seeds constitute the most important larval feeding niche (56.0%), far more important than leaves (24.0%) and roots (20.0%). Almost all these species are only present in man-made habitats which represent 94.1% of the colonized habitats, essentially agricultural lands, parks and gardens, glasshouses, and warehouses for seed beetles (Figure 8.3.5). Natural and semi-natural habitats have been very little colonized yet.

In addition to these strong habitat trends, about 40% of the alien chrysomelid species remain strictly related to their original, alien plants. This is especially true for leaf beetles, where only *Epitrix hirtipennis* out of the 11 alien species has been observed to shift onto native Solanaceae in Italy (Beenen 2006). In contrast, most alien seed beetles found outdoors have already switched to seeds of native plants, for example *Bruchidius siliquastri* on the native redbud, *Cercis siliquastrum,* in France (Kergoat et al. 2007), and *Acanthoscelides obtectus* and *Callosobruchus chinensis* on wild legumes (Tuda et al. 2001). Under outdoor conditions, a strict dependency to the original alien host was only observed for two *Megabruchidius* species, *M. tonkineus* and *M. dorsalis*, associated with seeds of honey locust tree, *Gleditsia triacanthos,* in parks and gardens. However, a number of seed beetle species still confined to greenhouses and warehouses only develop on alien hosts of tropical origin, such as *Caryedon serratus* associated with

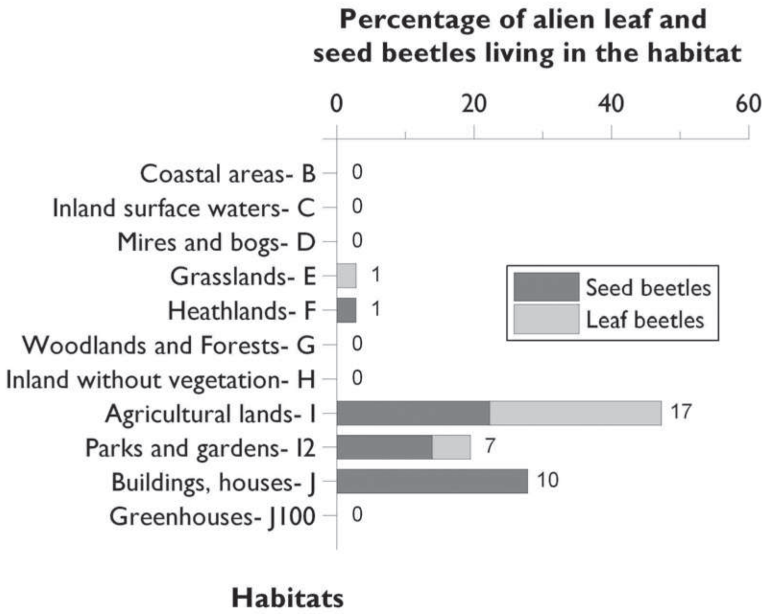

Figure 8.3 5. Main European habitats colonized by the established alien species of Chrysomelidae and Bruchidae. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

groundnuts (*Arachis hypogaea* L.), tamarind (*Tamarindus indica* L.) and other seeds of alien Caesalpinioideae (Kingsolver 2004). Such species still cannot establish outdoors because none of their alien hosts can survive in the wild at the present time.

8.3.7 Ecological and economic impact

Threats due to alien chrysomelid species were first pointed out by Linnaeus in a lecture in 1752, referring to his observation of asparagus plants (*Asparagus officinalis* L.) that were heavily infested in the vicinity of Hamburg by *Crioceris asparagi,* a species introduced from Russia at this time (Aurivillius 1909).

Alien chrysomelid species are better known for their economic impact than for their ecological impact. Indeed, possible ecological impacts on native flora and fauna are very little documented. Positive impact can be appreciated for only one alien species, *Zygogramma suturalis*, a strict monophagous species deliberately introduced to Europe for the control of the invasive ragweed (cf above).

Negative economic impacts have been recorded in seven of the alien seed beetle species which may severely affect stored pulses of economically-important legumes (*Acanthoscelides obtectus, A. pallidipennis, Bruchus pisorum, B. rufimanus, Callosobruchus chinensis, C. maculatus, C. phaseoli*, and *Zabrotes subfasciatus*; see (Borowiec 1987, Hoffmann et al. 1962)). Most of them are capable of re-infesting stored legumes until the food reserves are exhausted. In leaf beetles, large economic impacts have been shown for the Colorado potato beetle, *L. decemlineata*, affecting potato crops (see factsheet 14.10) and the western corn rootworm, *D. virgifera virgifera* affecting maize roots and foliage (see factsheet 14.8). However, It must be stressed that economic damage has only been seen on maize in Serbia, and in some bordering areas in Croatia, Hungary, Romania, and small areas in Bosnia-Herzegovina and Bulgaria (EPPO 2009). In the United Kingdom, yield losses to be expected from the arrival and spread of *D. virgifera virgifera* have been estimated to range from 0.9 to 4.1 million € over 20 years in absence of obligatory campaign to prevent spread of western corn rootworm but the costs of such a campaign could also range from 3.7 to 10.5 million € (Central Science Laboratory 2007). *Epitrix hirtipennis* may also impact tobacco crops (Sannino et al. 1984, Sannino et al. 1985) as well as *E. cucumeris* these of potato and tomato (Borges and Serrano 1989), and *Phaedon brassicae* the cabbage crops (Limonta and Colombo 2004). Alien foliage-feeding chrysomelids may also act as vectors for plant diseases, for example *D. virgifera* which transmits several cowpea virus strains in North America (Lammers 2006). However, little is yet known in this field (Jolivet and Verma 2002). Besides such economic damage, aesthetic impacts are recorded on ornamental plants, such as these of the leaf beetle *Pistosia dactylifera* on palm trees in southern France (Drescher and Martinez 2005).

8.3.8 Expected trends

Introduction of alien chrysomelids is still an ongoing process, especially through the trade of ornamentals via garden centers. For example, an alien species of the genus *Luperomorpha* was recently imported to Europe. *L. xanthodera*, originating from China, was first found in Great Britain feeding in flowers of several plant species in garden centers (Johnson and Booth 2004). Later it was observed in Switzerland (F. Köhler, personal communication), Germany (Döberl and Sprick 2009) and the Netherlands (Beenen et al. 2009), and also in garden centers, especially on rose flowers (Figure 8.3.6). Other alien specimens of *Luperomorpha* observed in Italy (Conti and Raspi 2007) and France (Doguet 2008) were first identified as *L. nigripennis*, from India and Nepal, but finally identified as *L. xanthodera* (Döberl and Sprick 2009). Plants cultivated in the Mediterranean area, then transported without severe pest control and sold in Central, Western and Northern Europe also constitute a serious threat for the expansion of species alien *in* Europe. The risks associated to this pathway were estimated for Norway (Staverløkk and Saethre 2007).

Species originating from subtropical and tropical regions have also been translocated such as *Aspidimorpha nigropunctata* (Klug) from tropical Africa to The Netherlands and *Macrima pallida* (Laboissière) from the Himalayan region to Cyprus. These introductions usually have not led to establishment (Beenen 2006). However, they do indicate a potential risk, especially in the context of global warming which may facilitate establishments of such species in the near future. The arrival in southern Europe of additional species associated with ornamental palms such as the hispine leaf beetle, *Brontispa longis-*

Figure 8.3.6. Adult of alien flea beetle, *Luperomorpha xanthodera* (Credit: Urs Rindlisbacher- Foto: www.insektenwelt.ch)

Figure 8.3.7. Adult of alien seed beetle, *Specularius impressithorax*; a- dorsal view; b- lateral view (credit: C. van Achterberg; photo taken using Olympus stereomicroscope SZX12 with AnalySIS Extended Focal Imaging software).

Figure 8.3.8. Adult of Mexican bean weevil, *Zabrotes subfasciatus*. a- dorsal view; b- lateral view (credit: C. van Achterberg; photo taken using Olympus stereomicroscope SZX12 with AnalySIS Extended Focal Imaging software)

sima (Gestro), already invasive in other parts of the world (Nakamura et al. 2006), is thus probable, considering the current increase in alien pests related to palms (see Chapter X).

Finally, it is difficult to make serious predictions about the results of future translocations because the species may react differently to the new habitats and hosts when compared with the situation in their native environment. Furthermore, translocations may enhance evolutionary changes partly because of founder effects and genetic bottlenecks and partly because of the triggering of evolution by new environmental factors (Whitney and Gabler 2008). *Zygogramma suturalis* when introduced to the Northern Caucasus for biological control of ragweed, showed rapid evolutionary changes in flight capacity (development of flight ability and morphological changes) within only five generations (Kovalev 2004).

References

Aurivillius C (1909) Carl von Linné als Entomolog. Verlag von Gustav Fischer.

Baca F (1994) [New member of the harmful entomofauna of Yugoslavia, *Diabrotica virgifera virgifera* LeConte (Coleoptera, Chrysomelidae)] (in serbo-croatian). *Zastita Bilja* 45: 125–131.

Baker CRB, Blackman RL, Claridge MF (1972) Studies on *Haltica carduorum* Geurin (Colepotera: Chrysomelidae) an alien beetle released in Britain as a contribution to the biological control of creeping thistle, *Cirsium arvense* (L.) Scop. *Journal of Applied Ecology* 9: 819–830.

Bartlett PW (1980) Interception and eradication of Colorado beetle in England and Wales, 1958–1977. *Bulletin OEPP/EPPO Bulletin* 10: 481–490.

Beenen R (1992) Een bijzondere voedselplant voor een bijzondere bladkever. *Natuurhistorisch Maandblad* 81: 220.

Beenen R (2006) Translocation in leaf beetles (Coleoptera: Chrysomelidae). *Bonner zoologische Beiträge* 54 [2005]: 179–199.

Beenen R, unpublished records.

Beenen R, Winkleman JK (2001) Aantekeningen over Chrysomelidae in Nederland 5. *Entomologische Berichten, Amsterdam* 61: 63–67.

Beenen RJ, Winkelman F van Nunen, Vorst O (2009) Aantekeningen over Chrysomelidae (Coleoptera) in Nederland 9. *Entomologische Berichten, Amsterdam* 69: 9–12.

Binaghi G (1947) Un nuovo tonchio introdotto dal Brasile. *Giornale di Agricoltura* 57: 4.

Biondi B, Daccordi M, Regalin R, Zampetti M (1994) Coleoptera Polyphaga XV (Chrysomelidae, Bruchidae). In: Minelli A, Ruffo S, La Posta (Eds) *Check list delle specie della fauna italiana 60*. Bologna: Calderini. 34 pp.

Böhme J (2001) Phytophage Käfer und ihre Wirtspflanzen in Mitteleuropa. Ein Kompendium. Heroldsberg: Bioform.

Borges PAV, Serrano ARM (1989) New records of the Coleopterous fauna (Insecta, Coleoptera) from the Azores. *Boletim do Museu Municipal do Funchal* 41: 5–24.

Borges PAV, Vieria V, Dinis F, Jarroca S (2005) *A list of terrestrial fauna (Mollusca and Arthropoda) and flora (Nryophyta, Pteridophyta and Spermatophyta) from the Azores*. Horta, Angra do Hero: Direcçao Regional do Ambiente and Unversidade dos Açores.

Borowiec, L. (1983) A survey of seed-beetles of Bulgaria (Coleoptera, Bruchidae). *Polsk. Pismo Entomol.* 53: 107–127.

Borowiec L (1987) The genera of seed-beetles (Coleoptera, Bruchidae). *Polskie Pismo Entomologiczne* 57: 3–207.

Borowiec L (1988) *Fauna Polski, Tom 11, Bruchidae*. Polska Akad. Nauk. Inst. Zool., Warszawa. 225 pp.

Bouchelos CT, Chalkia CA (2003) [First record in Greece of seed-eating insect of Gazia] (in Greek). *Georgia Ktinotrofia,* 3: 22–24.

Buckland PC, Skidmore P (1999). *Xanthogaleruca luteola* (Müller) (Chrysomelidae) in Britain. *The Coleopterist* 8: 97–99.

CABI/EPPO, 2003. *Leptinotarsa decemlineata, Distribution Maps of Plant Pests 139*. Wallingford, UK: CAB International.

Central Science Laboratory (2007) Cost Benefit Analysis for *Diabrotica virgifera virgifera.* http://www.defra.gov.uk/planth/phnews/diab07.pdf.

Ciosi M, Miller NJ, Kim KS, Giordano R, Estoup A, Guillemaud T (2008) Invasion of Europe by the western corn rootworm, *Diabrotica virgifera virgifera*: multiple transatlantic introductions with various reductions of genetic diversity. *Molecular Ecology* 17: 3614–3627.

Conti B, Raspi A (2007) Prima segnalazione in Italia di *Luperomorpha nigripennis* Duvivier (Coleoptera Chrysomelidae). *Informatore Fitopatologico* 57: 51–52.

Cox ML (1995) *Psylliodes cucullata* (Illiger, 1807) (Coleoptera: Chrysomelidae: Alticinae) - a species new to Britain. *Entomologist's Gazette* 46*:* 271–276.

Cox ML (2007) *Atlas of the seed and leaf-beetles of Britain and Ireland*. Oxford: Information Press. 336 pp.

Cruz RT de la (2003) Understanding 'Orchid lema'. BAR digest 5, no 3. Available at [www.bar.gov.ph/bardigest/2003/julsep03_orchidlema.asp]. Retrieved August 4 2008.

Del Bene G, Conti B (2009). Notes on the biology and ethology of *Luperomorpha xanthodera*, a flea beetle recently introduced into Europe. *Bulletin of Insectology 62: 61–68***.**

Delobel A, Delobel B (2003) Les plantes hôtes des bruches (Coleoptera Bruchidae) de la faune de France, une analyse critique. *Bulletin de la Société linnéenne de Lyon* 72: 199–221

Döberl M (1994a) Bemerkenswerte Alticinenfunde aus Westeuropa (Col., Chrysomelidae). *Entomologische Nachrichten und Berichte* 38: 179–182.

Döberl M (1994b) Auffällige Ausbreitung einiger Alticinen-Arten in Westeuropa (Coleoptera, Chrysomelidae, Alticinae). *Verhandlungen des 14. Internationalen Symposiums für Entomofaunistiek in Mitteleuropa, München, SIEEC*: 276–280.

Döberl M (2000) Beitrag zur Kenntnis der Gattung *Epitrix* Foudras, 1860 in der Paläarktis. Mitt. Internat. *Mitteilungen des internationalen Entomologischen Vereins Frankfurt* 25: 1–23.

Döberl M, Sprick P (2009). *Luperomorpha* Weise, 1887 in Western Europe (Coleoptera: Chrysomelidae: Alticinae). *Entomologische Blätter* 105: 51–56.

Doguet S (2008) Présence en France de *Luperomorpha nigripennis* Duvivier, 1892. (Col. Chrysomelidae, Alticinae). *Le Coléoptériste* 11: 62–63.

Doguet S (2009) Présence en Europe de deux espèces nord-américaines d'*Epitrix* (Coleoptera Chrysomelidae Alticinae). *L'Entomologiste* 65 : 89–90.

Drescher J, Martinez M (2005) Le coléoptère *Pistosia dactyliferae* menace les palmiers du sud de la France. *PHM - Revue Horticole* 468: 34–35.

EPPO, 2006. *Leptinotarsa decemlineata*. In: *PQR database (version 4.5)*. Paris, France: European and Mediterranean Plant Protection Organization. www.eppo.org.

EPPO (2009). Present situation of Diabrotica virgifera in Europe. 2008. http://www.eppo.org/QUARANTINE/Diabrotica_virgifera/diabrotica_virgifera.htm#map-dia. [accessed March 1, 2010].

Essl F, Rabitsch W (Eds) (2002) Neobiota in Österreich. Wien: Umweltbundesamt. 432 pp.

Fauna Europaea. http://www.faunaeur.org/.

Gobierno de Canarias (2010). Especies introducidas en Canarias. http://www.interreg-bionatura.com/especies/index.php?opt=verDatos#. [accessed March 1, 2010].

Gödöllo University. Spread of Western Corn Rootworm in Europe. Maps 2000–2004. http://w3.mkk.szie.hu/dep/nvtt/wcrnet/wcrnet-2.htm.

Grapputo A, Boman S, Lindström L, Lyytinen A, Mappes J (2005) The voyage of an invasive species across continents: genetic diversity of North American and European Colorado potato beetle populations. *Molecular Ecology* 14: 4207–4219.

Gruev B (1981) A new species of *Epitrix* Foudras from the Azores (Insecta, Coleoptera, Chrysomelidae). *Boletim da Sociedade Portuguesa de Entomologia* 10: 1–2.

Gruev B, Döberl M (2005) *General distribution of the flea beetles in the Palaearctic subregion (Coleoptera, Chrysomelidae: Alticinae*. Sofia and Moscow: Pensoft, Supplement Series Faunistica No 42. 239 pp.

Gu J, Mao YQ, Wang LP, Xu JJ, Zhang Y, Du YZ (2009) [Genetic differentiation among different geographic populations of the cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae)] (in Chinese, English abtsract). *Acta Entomologica Sinica* 52: 1349–1355.

Guillemaud T, Beaumont MA, Ciosi M, Cornuet JM, Estoup A (2010) Inferring introduction routes of invasive species using approximate Bayesian computation on microsatellite data. *Heredity* 104: 88–99.

György Z (2007) To the biology of the honey locust seed beetle, *Megabruchidius tonkineus* (Pic, 1904) (Coleoptera: Chrysomelidae: Bruchinae). *Folia Entomologica Hungarica* 68 : 89–96.

Hansen M (1996) [Katalog over Danmarks biller] Catalogue of the Coleoptera of Denmark. *Entomologiske Meddelelser* 64: 1–231.

Hansen V. (1964) [Fortegelse over Danmarks biller] Catalogue of the Coleoptera of Denmark. *Entomologiske Meddelelser* 33: 1–507.

Heetman AJA, Beenen R (2008) Twee exotische zaadkevers ingevoerd met bonen (Coleoptera, Bruchidae). *Entomologische Berichten*, 68: 187–188.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England*. Peterborough, UK: Report to English Nature N°662.

Hodge PJ (1997) *Bruchidius varius* (Olivier) (Chrysomelidae) new to the British. Isles. *The Coleopterist* 5: 65–68.

Hoffmann A (1945) *Coléoptères Bruchidae et Anthribidae*. Faune de France 44. Paris: Lechevallier. 184 pp.

Hoffmann J, Labeyrie V Balachowsky AS (1962) Les Bruchidae. In: Balachowsky AS (Ed) *Entomologie appliquée à l'agriculture*, Tome 1, Volume 2. Paris : Masson, 434–494.

Hurst GW (1970) Can the Colorado potato beetle fly from France to England ? Entomologist's Monthly Magazine 105: 269–272.

Igrc J, Deloach CJ, Zlof V (1995) Release and Establishment of *Zygogramma suturalis* F (Coleoptera: Chrysomelidae) in Croatia for Control of Common Ragweed (*Ambrosia artemisiifoli*a L.). *Biological Control* 5: 203–208.

Izquierdo I, Martín JL, Zurita N, Arechavaleta M (2004) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias; Santa Cruz de Tenerife.

Jermy T, Szentesi Á, Anton KW (2002) *Megabruchidius tonkineus* (Pic, 1904) (Coleoptera: Bruchidae) first found in Hungary. *Folia entomologica hungarica* 63: 49–51.

Johnson C (1963) *Chrysolina americana* (L.) (Col. Chrysomelidae) in Britain. *Entomologist's Monthly Magazine* 99: 228–229.

Johnson C, Booth RG (2004) *Luperomorpha xanthodera* (Fairmaire): a new British flea beetle (Chrysomelidae) on garden centre roses. *The Coleopterist* 13: 81–86.

Jolivet P (2001) Vers la mondialisation des Chrysomelides? *L 'Entomologiste* 57: 123–141.

Jolivet P, Verma KK (2002) Biology of Leaf Beetles. Andover, Hampshire, UK: Intercept Publishers. 332 pp.

Kergoat GJ, Delobel P, Delobel A (2007) Phylogenetic relationships of a new species of seed-beetle infesting *Cercis siliquastrum* L. in China and in Europe (Coleoptera: Chrysomelidae: Bruchinae: Bruchini). *Annales de la Société Entomologique de France* 43: 265–271.

Kingsolver JM (2004) *Handbook of the Bruchidae of the United States and Canada (Insecta, Coleoptera)*. United States Department of Agriculture: Technical Bulletin 1912. 324 pp.

Kovalev OV (2004) The solitary population wave, a physical phenomenon accompanying the introduction of a chrysomelid. In: Jolivet P, Santiago-Blay JA, Schmitt M (Eds) *New developments in the biology of Chrysomelidae*. Amsterdam: SPB Academic Publishing, 591–601.

Lammers W (2006) *Report of a Pest Risk Analysis*. Netherlands Plant Protection Service.

Lays P (1988) *Chrysolina americana* (Linné) Belg. nov. sp. (Coleoptera, Chrysomelidae, Chrysomelinae), une espèce mediterranéenne en Belgique. *Bulletin et Annales de la Société Royale. Belge d'Entomologie* 124: 29–33.

Limonta L, Colombo M (2004) Record in Italy of *Phaedon brassicae* Baly (Coleoptera Chrysomelidae Chrysomelinae). *Bollettino di Zoologia Agraria e di Bachicoltura* Serie II 36(3), 369–371.

Michieli G (1957) Ricerche sulla biologia della *Phytodecta fornicata* Bruggem. (Col. Chrysomelidae) e del suo parassita *Meigenia floralis* Fall. (Diptera Larvevoridae). *Bollettino del Museo Civico di Storia Naturale di Venezia* 10: 49–86.

Migliaccio E, Zampetti MF (1989) *Megabruchidius dorsalis* e *Acanthoscelides pallidipennis*, specie nuove per la fauna italiana (Coleoptera, Bruchidae). *Bollettino Associazione Romana di Entomologia* 43: 63–69.

Miller N, Estoup A, Toepfer S, Bourguet D, Lapchin L, Derridj S, Kim KS, Reynaud P, Furlan L, Guillemaud T (2005) Multiple transatlantic introductions of the western corn rootworm. *Science* 310: 992.

Mohamedsaid MS (2004) Catalogue of the Malaysian Chrysomelidae (Insecta: Coleoptera). Sofia & Moscow: Pensoft. 239 pp.

Nakamura S, Konishi K, Takasu K (2006) Invasion of the coconut beetle, *Brontispa longissima*: Current situation and control measures in Southeast Asia. In: *Food and Fertilizer Technology Center (FFTC) meeting 'Development of Database (APASD) for Biological Invasion'*, Taichung, Taiwan September 2006, ROC. www.agnet.org/activities/sw/2006/589543823/paper-899851121.pdf .

Oliviera R, Chatot C, Dedryver CA (2008) Détectée en Europe, une nouvelle altise. *Potato Planet*: 30–34.

Pinhasi R, Fort J, Ammerman AJ (2005) Tracing the origin and spread of agriculture in Europe. *PLoS Biology* 3: e410.

Purdue University. Map of expansion of Western Corn Rootworm in Europe in 2008. http://extension.entm.purdue.edu/wcr/images/jpg/2008/EUROPE08.jpg.

Ramos YR, Fernández-Carrillo JL, Fernández-Carrillo E (2007) Sobre la presencia del gorgojo de las acacias, *Pseudopachymerina spinipes* (Erichson, 1833) en la Península Ibérica (Coleoptera: Bruchidae). *Boletín la Sociedad Entomologica Aragonese* 40: 511–522.

Reid CAM (1995) A cladistic analysis of subfamilial relationships in the Chrysomelidae sensu lato (Chrysomeloidea). In: Pakaluk J, Slipinski SA (Eds) *Biology, phylogeny, and classification of Coleoptera*. Papers celebrating the 80th birthday of Roy A. Crowson. Warszawa: Muzeum i Ynstitut Zoologii PAN, 559–631.

Reznik SYa, Volkovitsh MG, Dolgovskaya MYu, Cristofaro M (2004) Introduction of the ragweed leaf beetle *Zygogramma suturalis* (Coleoptera, Chrysomelidae) into Russia for biological control of common ragweed *Ambrosia artemisiifolia* (Asteraceae) as a model of biological invasion. In: *Abstract Proceedings of Neobiota, 3rd International Conference on Biological Invasions,* Bern, Switzerland, September - October 2004, 111.

Sainte-Claire Deville J (1938) Catalogue raisonné des Coléoptères de France. *L'Abeille* 36: 373–467.

Sannino L, Balbiani A, Espinosa B (1984) Un nuovo fitofago devasta il tabacco nel beneventano: *Epithrix hirtipennis* Melsch. *Informatore Agrario* 29: 55–57.

Sannino L, Balbiani A, Biondi M (1985) *Epitrix hirtipennis* (Melsheimer, 1847) (Coleoptera, Chrysomelidae): Considerazioni tassonomiche, ecologich ed etologiche. Atti XIV Congresso nazionale Italiano Entomologia, Palermo: 285–292.

Simmonds MSJ, Blaney WM, Birch ANE (1989) Legume Seeds: the Defences of Wild and Cultivated Species of *Phaseolus* Against Attack by Bruchid Beetles. *Annals of Botany* 63: 177–184.

Southgate BJ (1979) Biology of the Bruchidae. *Annual Review of Entomology* 24: 449–473.

Staverløkk A, Saethre MG (2007) Stowaways in imported horticultural plants: alien and invasive species – assesing their bioclimatic potential in Norway. *Bioforsk Report* 2, N°66. 70 pp.

Stephens JF (1839) A Manual of British Coleoptera or Beetles. London: Longman, Orme Brown, Green & Longmans. 443 pp.

Strejček J (1990) *Brouci celedí Bruchidae, Urodontidae a Anthribidae*. Praha : Academia. 88 pp.

Strejček J (1993) Faunistic records from the Czech Republic 9. *Klapalekiana* 29: 169–171

Szentesi, A. (1999) Predispersal seed predation of the introduced false indigo, *Amorpha fruticosa* L. in Hungary. *Acta Zool. Acad. Sci. Hung*. 45: 125–141.

Tomov R, Trencheva K, Trenchev G, Kenis M (2007) A review of the non-indigenous insects of Bulgaria. *Plant Science* 44: 199–204.

Tuda M, Shima K, Johnson CD, Morimoto K (2001) Establishment of *Acanthoscelides pallidipennis* (Coleoptera: Bruchidae) feeding in seeds of the introduced legume *Amorpha fruticosa*, with a new record of its *Eupelmus* parasitoid in Japan. *Applied Entomology and Zoology* 36: 269–276.

Tuda M, Rönn J, Buranapanichpan S, Wasano N, Arnqvist G (2006) Evolutionary diversification of the bean beetle genus *Callosobruchus* (Coleoptera: Bruchidae): traits associated with stored-product pest status. *Molecular Ecology* 15: 3541–3551.

Valosaari KR, Aikio S, Kaitala V (2008) Spatial simulation model to predict the Colorado potato beetle invasion under different management strategies. *Annales Zoologici Fennici* 45: 1–14.

Wendt H (1980) Erstmaliges Auftreten des Vorratsschädlings, *Bruchidius tonkineus* (Pic, 1904) in der DDR. *Deutsche Entomologische Zeitschrift* 27: 317–318.

Wendt, H. (1981) Eine für Sudost-Europa neue Samenkäfer-Art (Coleoptera: Bruchidae). *Folia Entomologica Hungarica* 42: 223–226.

Whitney KD, Gabler CA (2008) Rapid evolution in introduced species, 'invasive traits' and recipient communities: challenges for predicting invasive potential. *Diverstity and Distributions* 14: 569–580.

Zangheri S (1960) L'*Aspidimorpha cincta* F. (Coleoptera Chrysomelidae, Cassidinae) in Italia. *Bollettino di Zoologia agraria e di Bachicoltura Ser. II* 3: 219–220.

Table 8.3.1. List and characteristics of the established Chrysomelidae species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 1 February 2010.

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Alticinae- flea beetles								
Epitrix cucumeris (Harris, 1851)	A	Phyto-phagous	Central and South America	1987, PT-AZO	PT-AZO	I1	*Nicotiana* and other Solanaceae	Borges and Serrano (1989)
Epitrix hirtipennis (Melsheimer, 1847)	A	Phyto-phagous	Southern USA, Central and South America.	1984, IT	BG, GR, IT, MK, PT-AZO	I1	*Nicotiana* and other Solanaceae	Döberl (1994b), Döberl (2000), Sannino et al. (1984), Sannino et al. (1985)
Epitrix similaris Gentner, 1944	A	Phyto-phagous	USA	2008, PT	PT	I1	*Solanum tuberosum*	Doguet (2009), Oliviera et al. (2008)
Luperomorpha xanthodera (Fairmaire, 1888)	A	Phyto-phagous	China, Korea	2003, GB	CH, DE, FR, GB, IT, NL	I2	*Iris* and *Euonymus* roots (larva); adult polyphagous	Beenen, unpubl., Conti and Raspi (2007), Del Bene and Conti (2009), Delobel and Delobel (2003), Doguet (2008), Johnson and Booth (2004)
Bruchidae – seed beetles								
Acanthoscelides obtectus Say, 1831	A	Phyto-phagous	C & S America	1889, IT	AL, AD, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IL, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MT, NL, NO, NO-SVL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	J1, I	*Phaseolus* seeds, wild and cultivated legumes outdoors	Borges et al. (2005), Delobel and Delobel (2003), Hoffmann et al. (1962), Tomov et al. (2007)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Acanthoscelides pallidipennis (Motschulsky, 1874)	A	Phyto-phagous	North America	1980, BG	AT, BA, BG, CH, CZ, DE, HR, HU, IT, LU, MK,PL, RO, RS	I, J	*Amorpha fruticosa* (indigobush) and other legumes	Borowiec (1983), Borowiec (1988), Migliaccio and Zampetti (1989), Szentesi (1999), Wendt (1981)
Bruchidius siliquastri Delobel 2007	C	Phyto-phagous	Crypto-genic	2003, FR	FR	I2	*Cercis* seeds	Kergoat et al. (2007)
Bruchus pisorum (Linnaeus, 1758)	A	Phyto-phagous	Asia-Temperate	1850, CZ	AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MO, MT, NL, NO, NO-SVL, PL, PT, PT-AZO, PT-MAD, PT, RO, RS, RU, SE, SI, SK, UA	I, J1	Dried peas; *Lathyrus, Pisum, Vicia*	Delobel and Delobel (2003), Fauna Europaea (2009), Gobierno de Canarias (2010), Hoffmann (1945), Sainte-Claire Deville (1938)
Bruchus rufimanus Bohemann, 1833	A	Phyto-phagous	Africa	1894, PT	AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MT, NL, NO, NO-SVL, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	I, J1	Stored beans; *Phaseolus, Vicia, Lathyrus, Lupinus, Pisum, Lens, Cicer* (wild and cultivated)	Delobel and Delobel (2003), Fauna Europaea (2009), Gobierno de Canarias (2010), Hoffmann (1945), Sainte-Claire Deville (1938)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Callosobruchus chinensis (Linnaeus, 1758)	A	Phyto-phagous	Asia-Temperate	1878, FR	AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IL, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MT, NL, NO, NO-SVL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	I, J1	Stored legumes (capable of re-infesting)	Biondi et al. (1994), Essl and Rabitsch (Eds) (2002), Fauna Europaea (2009), Gobierno de Canarias (2010), Hoffmann (1945), Sainte-Claire Deville (1938), Tomov et al. (2007)
Callosobruchus maculatus (Fabricius, 1775)	A	Phyto-phagous	Africa	1878, FR	AL, BG, CZ, ES, FR, GR, GR-CRE, IL, IT, IT-SIC, IT, PT, PT-AZO	I, J1	*Phaseolus* and other stored legumes (capable of re-infesting)	Binaghi (1947), Delobel and Delobel (2003), Fauna Europaea (2009), Gu et al. (2009), Hoffmann (1945), Tomov et al. (2007)
Callosobruchus phaseoli (Gyllenhal, 1833)	A	Phyto-phagous	Asia-Temperate	1945, FR	AL, CZ, ES, FR, GR, GR-CRE, IL, IT, IT-SIC	I, J1	*Phaseolus, Lupinus* and other stored legumes (capable of re-infesting)	Delobel and Delobel (2003), Hoffmann (1945), Tomov et al. (2007)
Caryedon serratus (Olivier, 1790)	A	Phyto-phagous	Africa	1900, CZ	CY, CZ, DE, GR, GR-CRE	I1, I2, F, J1	*Acacia, Cassia, Prosopis* seeds	Delobel and Delobel (2003)
Megabruchidius dorsalis (Fahreus, 1839)	A	Phyto-phagous	Asia (Japan)	1989, IT	IT	I2	*Gleditsia* seeds	Migliaccio and Zampetti (1989)
Megabruchidius tonkineus György 2007	A	Phyto-phagous	Asia-tropical (Vietnam)	2001, HU	HU	I2	*Gleditsia* seeds	György (2007), Jermy et al. (2002)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Mimosestes mimose (Fabricius, 1781)	A	Phyto-phagous	Asia-Temperate	1945, FR	DE, DK, FR, IT	J1	*Acacia, Phaseolus, Vicia, Ciser* (chickpea) seeds	Hansen (1996), Hoffmann (1945)
Pseudopachymerina spinipes (Erichson, 1833)	A	Phyto-phagous	C & S America	1919, ES	ES, FR, GR, GR-CRE, IT, IT-SIC	I2	*Acacia farnesiana* seeds	Bouchelos and Chalkia (2003), Fauna Europaea (2009), Ramos et al. (2007)
Zabrotes subfasciatus (Bohemann, 1833)	A	Phyto-phagous	C & S America	1858, FR	AL, CZ, ES, ES-CAN, FR, GR, GR-CRE, IT, IT-SIC, NL, PT, PT-AZO	J1	*Phaseolus* and other stored legumes (capable of re-infesting)	Delobel and Delobel (2003), Hoffmann (1945)
Cassidinae – Tortoise leaf beetles								
Aspidomorpha fabricii Sekerka, 2008	A	Phyto-phagous	Africa	1957, IT	IT	I1	*Beta vulgaris*	Zangheri (1960)
Chrysomelinae – leaf beetles								
Leptinotarsa decemlineata (Say, 1824)	A	Phyto-phagous	North and Central America	1922, FR	AD, AL, AT, BA, BE, BG, BY, CH, CZ, DE, EE, ES, ES-BAL, FR, FR-COR, GR, HR, HU?, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MO, NL, PL, PT, RO, RS, RU, SE, SI, SK, UA	I1	*Solanum tuberosum* and other Solanaceae	CABI/EPPO (2003), EPPO (2006), Fauna Europaea, Grapputo et al. (2005), Tomov et al. (2007)
Phaedon brassicae Baly, 1874	A	Phyto-phagous	China, Japan, Taiwan, Vietnam.	2000, IT	IT	I1	Brassicaceae	Limonta and Colombo (2004)
Calligrapha polyspila (Germar, 1821)	C	Phyto-phagous	North America	> 2001, PT-AZO	PT-AZO		*Sida rhombifolia*	Jolivet (2001)

Family or subfamily *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat*	Hosts	References
Zygogramma suturalis (Fabricius, 1775)	A	Phyto-phagous	North America	1985, HR	HR		*Ambrosia artemisiifolia*	Igrc et al. (1995)
Galerucinae – Skeletonizing leaf beetles								
Diabrotica virgifera virgifera LeConte, 1868	A	Phyto-phagous	Central America	1992, RS	AT, BA, BE, BG, CH, CZ, DE, FR, GB, HR, HU, IT, MO, NL, PL, RO, RS, SI, SK, UA.	I1	*Zea mays*.	Baca (1994), Ciosi et al. (2007), EPPO (2009), Gödöllo University (2009), Guillemaud et al. (2010), Purdue University (2009)
Hispinae – Hispine leaf beetles								
Pistosia dactyliferae (Maulik, 1919)	A	Phyto-phagous	India	2004, FR	FR	I2	Palms	Drescher and Martinez (2005)

Table 8.3.2. List and characteristics of the Chrysomelidae species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 1 February 2010.

Family or subfamily *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Alticinae- flea beetles						
Altica ampelophaga Guérin-Méneville, 1858	Phyto-phagous	Western, Southern and Central Europe	PT-AZO	I	*Vitis*	Borges and Serrano (1989)
Altica carinthiaca Weise, 1888	Phyto-phagous	Continental Europe	GB	I2	*Lathyrus pratensis* (meadow vetchling)	Cox (2007)
Chaetocnema hortensis (Geoffroy, 1785)	Phyto-phagous	Continental Europe	PT-AZO	I	Graminae	Borges and Serrano (1989)
Epitrix pubescens (Koch, 1803)	Phyto-phagous	Continental Europe	PT-AZO	I	*Solanum*	Borges and Serrano (1989)
Longitarsus kutscherae (Rye, 1872)	Phyto-phagous	Continental Europe	PT-AZO	I	*Plantago*	Borges and Serrano (1989)
Longitarsus lateripunctatus lateripunctatus (Rosenhauer, 1856)	Phyto-phagous	Mediterranean region	PT-AZO	I	*Borago officinalis* and other Boraginaceae	Borges and Serrano (1989)
Longitarsus obliteratoides Gruev, 1973	Phyto-phagous	Continental Europe	GB	I2	*Thymus, Rosmarinus*	Cox (2007)
Neocrepidodera brevicollis (J. Daniel, 1904)	Phyto-phagous	Alps	DK	G3, G4	*Cirsium*	Hansen (1964)
Neocrepidodera ferruginea (Scopoli, 1763)	Phyto-phagous	Continental Europe, Caucasus	PT-AZO	I	Asteraceae and Poaceae	Borges and Serrano (1989)
Psylliodes chrysocephalus (Linnaeus, 1758)	Phyto-phagous	Continental Europe	PT-AZO	I	Brassicaceae	Borges and Serrano (1989)
Psylliodes cucullata (Illiger, 1807)	Phyto-phagous	Continental Europe	GB	I2	*Spergula arvensis* (Corn spurrey)	Cox (1995), Cox (2007)
Bruchidae – seed beetles						
Bruchidius foveolatus (Gyllenhal, 1833)	Phyto-phagous	Continental Europe	PT-AZO	I1	*Sarothamnus scoparius* seeds	Borges et al. (2005)

Family or subfamily *Species*	Regime	Native range	Invaded countries	Habitat*	Hosts	References
Bruchidius lividimanus (Gyllenhal, 1833)	Phyto-phagous	Mediterranean region	PT-AZO	I1	*Genistea, Ononis, Cytisus* seeds	Borges et al. (2005)
Bruchidius varius (Olivier)	Phyto-phagous	Continental Europe	GB	E, G	*Trifolium pratens* (red clover), *T. medium* (zig-zag clover), *Ulex europaeus* (gorse), *Bolboschoenus maritimus* (sea club-rush) seeds	Cox (2007), Hodge (1997)
Bruchus ervi Frölich, 1799	Phyto-phagous	Mediterranean region	BE, CH, CZ, DE, DK, ES-CAN, FI, GB, HU, IE, LI, LU, LV, NL, NO, PT-AZO, PT-MAD, RO, SE, SK, UA	I, J1	*Lens* seeds	Fauna Europaea (2009), Gobierno de Canarias (2010), Strejček (1990)
Bruchus lentis Fröhlich, 1799	Phyto-phagous	Southern Europe	ES-CAN	I, J1	*Lens, Vicia* seeds	Gobierno de Canarias (2010), Igrc et al. (1995)
Bruchus rufipes Herbst, 1783	Phyto-phagous	West Palaearctic	PT-AZO, ES- CAN	I	*Lathyrus, Pisum, Vicia* seeds	Borges et al. (2005), Gobierno de Canarias (2010)
Bruchus signaticornis Gyllenhal, 1833	Phyto-phagous	Mediterranean region	BE, CH, CZ, DE, DK, EE, FI, GB, HU, IE, LI, LT, LU, LV, MD, NL, NO, RU, SE, SK, UA	I, J1	*Lathyrus, Lens, Vicia* seeds	Strejček (1990)
Criocerinae- leaf beetles						
Crioceris asparagi (Linnaeus, 1758)	Phyto-phagous	Continental Europe, Central Asia	GB	I, J	*Asparagus officinalis officinalis* (garden asparagus), *A. officinalis prostratus* (wild asparagus)	Cox (2007), Hill et al. (2005)

Family or subfamily *Species*	Regime	Native range	Invaded countries	Habitat*	Hosts	References
Lilioceris lilii (Scopoli, 1763)	Phyto-phagous	Continental Europe	GB, IE	I2, I1	*Lilium, Fritillaria* and other Liliaceae; *Arum maculatum*	Cox (2007), Stephens (1839)
Cryptocephalinae – casebearers						
Cryptocephalus sulphureus G. A. Olivier, 1808	Phyto-phagous	Western Mediterranean	PT- AZO	I2	*Pulmonaria*	Borges and Serrano (1989)
Chrysomelinae – leaf beetles						
Chrysolina americana Linnaeus, 1758	Phyto-phagous	Mediterranean region	BE, GB, NL	I1, I2	*Rosmarinus, Lavandula, Salvia, Thymus*	Beenen and Winkleman (2001), Cox (2007), Johnson (1963), Lays (1988)
Chrysolina bankii (Fabricius, 1775)	Phyto-phagous	Mediterranean region	GB	I2	*Plantago lanceolata* (ribwort plantain), *Ballota nigra* (black horehound), *Mentha* spp., and other Lamiaceae	Cox (2007)
Gonioctena fornicata (Bruggemann, 1873)	Phyto-phagous	Eastern Europe	IT	I	*Medicago*	Michieli (1957)
Galerucinae- Skeletonizing leaf beetles						
Xanthogaleruca luteola (Müller, 1766)	Phyto-phagous	Europe	GB	I2	*Ulmus*	Buckland and Skidmore (1999)

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Ladybeetles (Coccinellidae) Chapter 8.4

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Abstract

The majority of Coccinellidae are beneficial predators and they have received considerable research attention because of their potential as biological control agents. Indeed the role of coccinellids as predators of pest insects has been a major factor in the movement of coccinellids between countries. The commercial production of coccinellids by biological control companies and local producers led to a rapid increase in distribution thoughout the 1990's. To date, 13 alien coccinellid species have been documented in Europe; 11 of these are alien to Europe (two are alien to Great Britain and Sweden but native within Europe). The distribution of alien coccinellids in Europe mirrors the biogeographical distribution and patterns of introduction. Some species have dispersed widely; *Harmonia axyridis* has spread rapidly from countries where it was deliberately introduced to many others across Europe. The ecological and economic impacts of alien coccinellids are not well documented. In this chapter we provide an overview of the temporal and spatial patterns of alien coccinellids in Europe.

Keywords

Coccinellid, ladybird, alien, Europe, biological control agent, *Harmonia axyridis*, distribution patterns

8.4.1 Introduction

The Coccinellidae are commonly referred to as ladybirds (Britain, Australia, South Africa), ladybugs (North America) or ladybeetles (various countries). Coccinellids have received considerable research attention because of their role as predators of pest insects. The Coccinellidae comprises over 4200 species worldwide (Iperti 1999, Majerus et al. (2006a)). Audisio and Canepari 2009 report that there are approximately 253 species and subspecies of Coccinellid in Europe. However, a review in 1999 documented only 110 species including species acclimatized through the 1900s: *Rodolia cardinalis*, *Cryptolaemus montrouzieri*, *Rhyzobius (Lindorus) lophanthae*, *Rhyzobius forestieri* and *Serangium parcestosum* (Iperti 1999). The discrepancy in species number from these different sources can not solely be accounted for by the addition of new species arriving in Europe but is an indication of the dynamic state of coccinellid taxonomy and the difficulty of establishing a checklist for Europe. Not only is the taxonomy of coccinellids under review but also the arrival of new species is ongoing; recently the UK Ladybird Survey (www.ladybird-survey.org) reported the first British record of *Cynegetis impunctata* (Thomas et al. 2009). There is also considerable variation in reported coccinellid diversity between countries. Great Britain is relatively species poor with only 46 species (Majerus et al. 2006b) whereas in contrast the Netherlands have 86 native coccinellid species. The proportion of alien species for this group is quite high in Europe, with 13 species observed in the wild to date. Two of these are native to Europe but alien within Great Britain (*Henosepilachna argus*, *Scymnus impexus*) and Sweden (*Scymnus impexus*). For the remainder of this section only the 11 species alien *to* Europe (and not the three alien species *in* Europe) will be considered.

The majority of coccinellid species (about 90 %) are beneficial predators (others are phytophagous or mycophagous); consequently coccinellids have played a significant role in the development of biological control strategies (Berthiaume et al. 2007, Brown and Miller 1998, Galecka 1991, Gurney and Hussey 1970, Iperti 1999, Obrycki and Kring 1998). This has been a major factor in the movement of coccinellids between countries worldwide.

8.4.2 Taxonomy of the coccinellid species alien to Europe

The family Coccinellidae belongs to the coleopteran superfamily Cucujoidea and is a member of the phylogenetic branch of Coleoptera termed the Cerylonid complex of families (Cerylonidae, Discolomidae, Alexiidae, Corylophidae, Endomychidae and Lathridiidae). Worldwide there are six subfamilies of Coccinellidae: Sticholotidinae, Chilocorinae, Scymninae, Coccidulinae, Coccinellinae and Epilachninae although a recent phylogeny suggests a seventh subfamily, Ortaliinae (Fürsch 1990, Kovář 1996). European species are mainly represented by three subfamilies: Scyminae, Chilocorinae and Coccinellinae. There are very few European Sticholotinae, very few Coccidulinae and only three species of Epilachninae (Iperti 1999). Although the species list for Coccinellidae in Fauna Europaea (Audisio and Canepari 2009) includes representatives from all six subfamilies.

Species alien *to* Europe are quite evenly represented between five of the six subfamilies. Three species are observed in the subfamily Coccidulinae (two Coccidulini and one Noviini) and in the Scymninae (two Scymnini and one Hyperaspidini). Two species are in the Chilocorinae (two Chilocorini) and Coccinellinae (two Coccinellini). One species is in the Sticholotidinae (Sticholotidini). There are no Epilachninae that are alien to Europe (although *Henosepilachna argus* is alien *in* Europe).

Most species in the Epilachninae are phytophagous, while the majority of species in the other subfamilies are predatory. The preferred diets of the two feeding stages in the life-cycle, the larval and adult stages, are generally the same. Most predatory ladybirds feed on either aphids or coccids (a few feed on both), however some predatory species feed on mites, adelgids, aleyrodids, ants, chrysomelid larvae, cicadellids, pentatomids, phylloxera, mycophagous coccinellids and psyllids (Dixon 2000). Indeed, a small number of species within the Coccinellinae and Epilachninae are mycophagous, feeding on the hyphae and spores of fungi. There is also considerable variability in the degree of dietary specialisation between species (Hodek 1996). Some species have a very narrow preferred prey range, such as a single species of mite, aphids of a single genus, or plants of a single family, other species have a wide prey range. *Harmonia axyridis*, for example, will feed on aphids, coccids, adelgids, psyllids, and the eggs and larvae of many other insects, including other coccinellids and lepidopterans (Legaspi et al. 2008, Ware and Majerus 2008). Ladybirds exhibit complex adaptations to specific or more general diets such as mandibular dentition, gut length and structure, and morphological features that affect mobility (Hodek 1996). Many predatory coccinellids will feed on alternative foods, such as pollen, nectar, honey-dew and fungi (many also resort to cannibalism) when preferred prey are scarce (De Clercq et al. 2005, Hodek 1996).

Coccinellids are distinguished from the remainder of the Cerylonid complex of families by a number of adult characteristics: five pairs of abdominal spiracles, tentorial bridge is absent, anterior tentorial branches are separated, frontoclypeal suture absent, apical segment of maxillary palpus never aciculate, galea and lacinia separated, mandible with reduced mola, front coxal cavities open posteriorly, middle coxal cavities open outwardly, metaepimeron parallel-sided, femoral lines present on abdominal sternite 2, tarsal formula 4-4-4 or 3-3-3, tarsal segment 2 usually strongly dilated below (Kovář 1996). In Europe, the diagnostic features of the family Coccinellidae can be considered in more simple terms (Majerus 2004). They are small to medium sized beetles (1.3–10 mm in length). There body shape is oval, oblong oval or hemispherical (upper surface convex and lower surface flat). They have large, compound eyes. The antennae are often 11-segmented but this figure varies and can be as low as seven. The mouthparts consist of large, strong mandibles; four-segmented maxillary palps (terminal segment axe shaped) behind the mandibles; labium divided into the pre-labium and post-labium; three-segmented labial palps; and the labrum. The head can be partly withdrawn under the pronotum. The pronotum is broader than long and has anterior extensions at the margin. The legs are short and can be retracted into depressions under the body. The tarsi are usually four segmented but the third segment is small and hidden in the end of the second segment. Each tarsus bears two claws. The abdomen has ten segments (Kovář 1996, Majerus et al. 2006a).

8.4.3 Temporal trends of introduction in Europe of alien coccinellids

The first species of coccinellid to be introduced into Europe was the vedalia beetle, *R. cardinalis,* for the control of the cottony cushion scale (coccid), *Icerya purchasi* (Figure 8.4.1). Two further species were introduced during the early twentieth century (mainly to the Mediterranean regions including France, Portugal and Italy) but there then followed a period of stagnation and respect to biological control in general. This correlates with the trend towards chemical insect pest control with the development of synthetic pesticides. From the 1980's onwards there were a considerable number of introductions on an extensive scale across Europe through the use of tropical coccinellids to control glasshouse pest insects.

8.4.4 Biogeography of the coccinellid species alien *to* Europe

Each continent has a specific fauna of coccinellidae. Belicek (1976) stated that "many species develop their cycles in life zones delineated by the general physiography of the continents (mountainous barriers) and climatic patterns combined with the types of vegetation in a given zone". Glaciation had profound effects on the distribution of coccinellids and the level of endemism is further controlled by ecological factors including temperature, food and natural enemies.

The temperate zones of Europe and North America are heavily infested by Aphidae and grasslands in these regions contain coccinellids from the tribus Coccinellini (*Coccinella* spp., *Adalia* spp., *Harmonia* spp.) and Hippodamiini, Cheilomenini and Scymnini. Open deciduous and coniferous forests in this temperate zone contain other genera of Coccinellini (*Anatis* spp., *Myrrha* spp., *Myzia* spp.). Tropical zones in central and South Africa, South America, India and China where Coccidae are abundant are characterised by coccinellids from the tribus Chilocorini (*Chilocorus* spp., *Exochomus* spp., *Brumus* spp.), Scymnini, Hyperaspini, Coccidulini and Noviini. In the Mediterranean regions of Europe, aphids and coccids are found together and are attacked by coccinellids from the temperate and tropical zones (Iperti 1999).

It is interesting to note that coccinellids native to temperate zones enter either simple quiescence or intense diapause as adults. In contrast, exotic species such as *Rhyzobius lophanthae* and *Cryptolaemus montrouzieri* do not enter quiescence or diapause but instead resist drastic changes in climate by reducing the speed of development during winter but not entirely stopping it (Iperti 1999).

The early introductions of alien coccinellids were characteristically as classical biological control agents; the predatory coccinellid originated from the same country as the target pest insect. So, for example, both *R. cardinalis* and *I. purchasi* originated from Australia; *R. lophanate* and various Diaspididae (*Pseudolacaspis pentagona*, *Quadraspidiotus perniciosus*, *Chrysomphalus dictyospermi*, *Parlatoria blanchardi*) from Australia and New Zealand; *C. montrouzieri* and *Planococcus citri* from Australia. Notably all these species are from tropical regions and were introduced into Mediterranean regions for

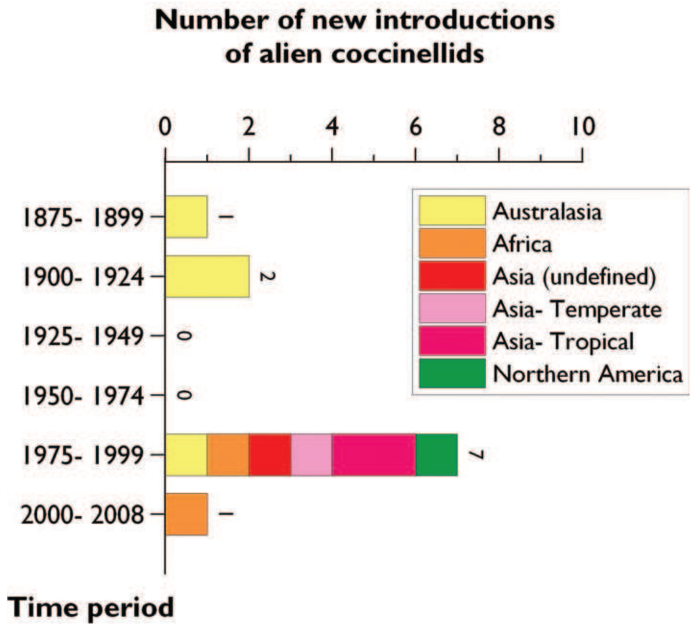

Figure 8.4.1. Temporal trends in the mean number of new records per year of coccinellid species alien *to* Europe from 1875 to 2008. The number above the bar indicates the total number of alien species newly recorded during the considered time period.

control purposes (Figures 8.4.1 and 8.4.2). In contrast, the coccinellid species selected to reinforce the activity of native natural enemies in temperate regions of Europe are from temperate regions of the globe for example, temperate Asia (*H. axyridis*) or North America (*Hippodamia convergens*).

8.4.5 Distribution of alien Coccinellids in Europe

The distribution of alien coccinellids in Europe mirrors the biogeographical distribution and patterns of introduction (Figure 8.4.3). Some species have dispersed widely; *H. axyridis* has spread rapidly from countries where it was deliberately introduced to many others across Europe. Furthermore, the commercial production of coccinellids by biological control companies and local producers led to a rapid increase in distribution thoughout the 1990's.

8.4.6 Use of alien coccinellids for biological control in Europe

The ecosystem service that predatory coccinellids provide in consuming pest insects has been recognised for over a century. The vedalia ladybird, *R. cardinalis*, is considered to have initiated modern biological pest control. It was released as a classical bio-

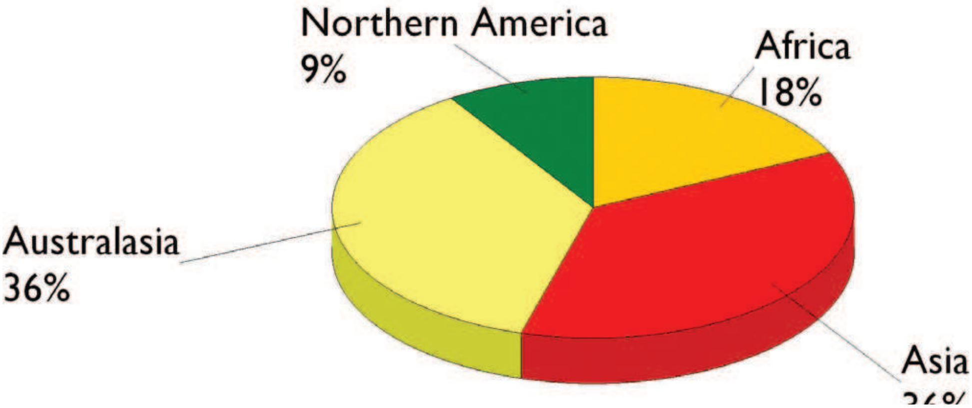

Figure 8.4.2. Origin of the 11 alien coccinellid species established in Europe.

logical control agent (native to Australia) in 1887 to control an alien cottony cushion scale (coccid), *I. purchasi*, which was threatening the citrus industry of California. The vedalia ladybird and the cottony cushion scale are still present in Californian citrus groves but the ecological balance between predator and prey ensures that the pest is no longer a problem (Caltagirone 1989, Majerus et al. 2006a).

The successful introduction of *R. cardinalis* for the control of *I. purchasi* resulted in considerable focus on Coccinellidae for importation programmes worldwide (Obrycki and Kring 1998). Over 40 species of coccinellid were introduced to North America following *R. cardinalis* during a period colloquially referred to as the "ladybird fantasy" (Caltagirone 1989, Dixon 2000). This worldwide phenomenon was mainly ineffectual; only four of over 40 species introduced to North America during this time established (Caltagirone 1989). In recent times there have been 155 attempts to control aphids and 613 to control coccids worldwide through the introduction of ladybirds (Dixon 2000). On a scale of success (complete, substantial, partial or no control) only one attempt to control aphids using coccinellids has been ranked as substantially successful and none have been completely successful (Dixon 2000). In contrast, 23 complete and 30 substantial successes have been achieved against coccids (Dixon 2000). In a few cases the introduced coccinellid species has had far-reaching, unacceptable impacts on biodiversity and so has been deemed an invasive species. *Harmonia axyridis*, harlequin ladybird, is the only such example in Europe (Brown et al. 2008a).

All of the 11 alien coccinellids in Europe have been intentionally released as biological control agents of pest insects. The first coccinellid to be introduced to Europe was *R. cardinalis* as a predator of *I. purchasi* in 1888 (Portugal), 1901 (Italy) and 1912 (Italy and France). This species was subsequently released through the mid and late 1900s to Italy, Portugal, Israel, France, Spain, Malta, Great Britain, Albania, Cyprus, Switzerland and the Ukraine. *Cryptolaemus montrouzieri*, native to Australia, was intentionally released to control mealybugs (Pseudococcidae), *Planococcus citri*, from 1908 in Italy. Subsequent releases were made in Spain (1926), Corsica (1970), France

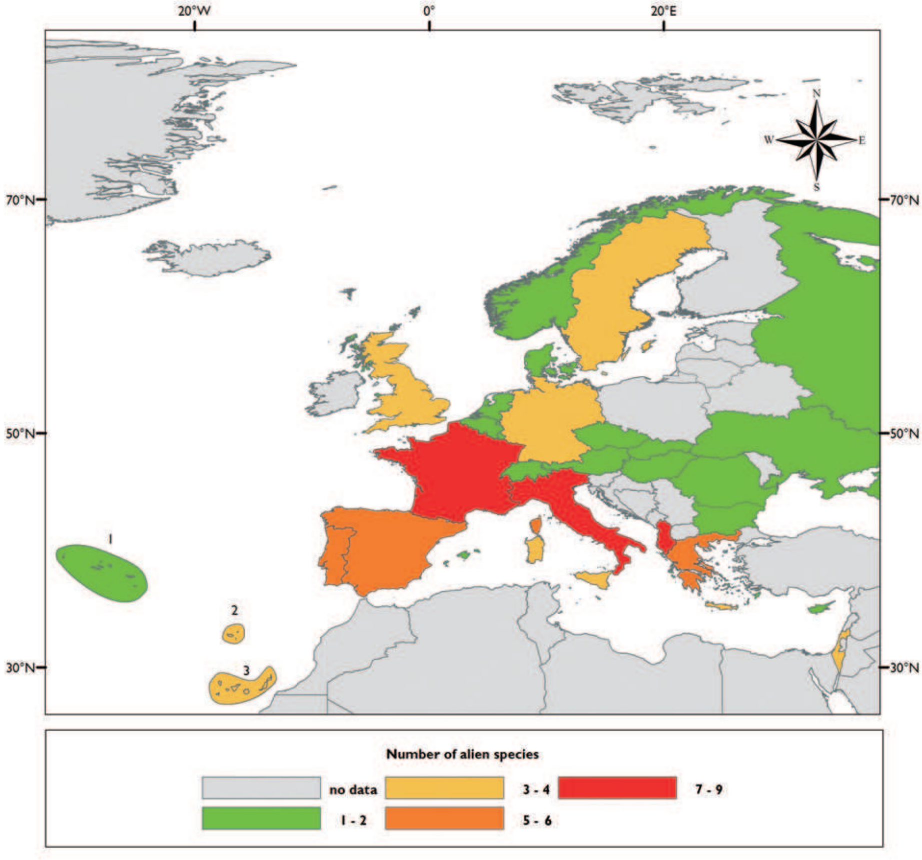

Figure 8.4.3. Colonisation of European countries and islands by coccinellids alien to Europe where known. Scale = total number of recorded alien coccinellids.

(1974), Portugal (1984) and Sweden (2001). This species is considered established in all the countries where it has been released other than Sweden (for which the status of this species is unknown). *Cryptolaemus montrouzieri* has been used extensively through augmentation (release of reared adults) and was the first coccinellid used to demonstrate an inoculative approach (whereby the aim is introduce a small number of individuals into a crop system with the expectation that they will reproduce and their offspring will continue to provide control of the target pest for an extended period of time). *Cryptolaemus montrouzieri* is easy and cheap to culture on mealybugs (Majerus 2004). *Rhyzobius lophanthae* is a species native to New Zealand which was introduced to Italy in 1908 for the control of Diaspididae (armoured scale insects). It has been released widely in European countries including: Portugal (1930 and 1984), Spain (1958), Sardinia (1973), France (1975), Greece (1977) and Germany (2000). This species has recently been reported as established in London, Great Britain (Natural History Museum, 2008).

Figure 8.4.4. Harlequin ladybeetle (*Harmonia axyridis*). Credit: Mark Bond

8.4.6.1 Control of Scale Insects

A number of coccinellid species have been used in historically significant and successful projects for the biological control of scale (Borges et al. 2006, Erler 2001, Katsoyannos 1997) including *R. cardinalis* and *R. lophanthae*. Other species introduced to Europe for control of scales include *Rhyzobius forestieri*, *Nephus reunioni*, *Chilocorus nigritus* and *Chilocorus kuwanae*.

Rhyzobius forestieri (native to Australia) has established in Italy, France, Greece and Albania. In the Cambos coastal plain of Greece this species is now considered the most abundant species of coccinellid within the coccidophagous guild (Katsoyannos 1997). *Nephus reunioni* (native to Africa) was intentionally released in a number of countries (Italy, Portugal, France, Greece, Albania and Spain) and is now considered to be established in Italy and Portugal. *Chilocorus nigritus* is native to the Indian sub-continent and South East Asia and is a candidate biological control agent for the control of species within the Coccoidea including three economically important families (Diaspididae, Pseudococcidae and Coccidae). It has a recent history, 1985 onwards, of introduction to a number of countries: Italy, Denmark, France, Germany, Netherlands, Great Britain and Albania. *Chilocorus kuwanae* is a biological control agent of scale insects and was introduced to Europe (Albania and Italy) from Asia in 1989.

8.4.6.2 Control of Aleyrodidae

The family Aleyrodidae comprises the commonly referred to whiteflies. Over fifty species of coccinellidae attack eggs and immature stages of whitefly pests (Obrycki and Kring 1998, Yigit et al. 2003). There is interesting variation in the preda-

Figure 8.4.5. Adults of *Cynegetis impunctata*. Credit: Gilles San Martin

tory behaviour of these polyphagous coccinellids; some are mobile, seeking out prey, and others are sedentary, and complete preimaginal development on one leaf (Obrycki and Kring 1998). In Europe one species, *Serangium parcesetosum*, has been introduced for the control of whitefly (*Bemisia tabaci*). *Serangium parcesetosum* was introduced from its native range of Asia and the Indian subcontinent to France including Corsica (Majka and McCorquodale 2006). A further species *Delphastus catalinae*, native to North America, has been introduced in glasshouses within Albania and Russia for the control of *Bemisia tabaci* and *Trialeurodes vaporariorum* (Kutuk and Yigit 2007, Legaspi et al. 2008). However, this species has not established in the wild. Studies on the thermal biology of *D. catalinae,* assessing the effects of temperature on development, voltinism and survival in the laboratory and field (non-indigenous range), indicate a strong correlation between survival in the laboratory at 5 °C and in the field in winter (Simmons and Legaspi 2004, Simmons and Legaspi 2007). *Delphastus catalinae* died out quickly in winter temperatures and this suggests that the probability of establishment is low in regions that experience low temperatures and scarcity of suitable food for part of the year (van Lenterenet et al. 2003). In the absence of studies on cold tolerance it is insufficient to assume that, on the basis of climate matching, winter would be an effective barrier to establishment of species originating from warmer climatic zones (van Lenteren et al. 2006). Risk assessments should also be sufficiently detailed to encompass strain specific parameters; the release of a non-diapausing strain versus a diapausing strain could result in very different impacts (van Lenteren et al. 2006). Furthermore, impacts through consumption of non-target hosts and dispersal require considerable attention (van Lenterenet et al. 2003). So, for example, although *D. catalinae* is not anticipated to survive winter temperatures in northern Europe, it is oligophagous

Figure 8.4.6. Adult of the phytophagous bryony ladybeetle, *Henosepilachna argus*. Credit: Mike Majerus.

and reported as an intra-guild predator of the aphelinid parasitoid *Encarsia sophia* (Zang and Liu 2007).

8.4.6.3 Control of Aphids

Hippodamia convergens and *H. axyridis* have both been released extensively throughout Europe for the control of aphids. *Hippodamia convergens* is native to America and several billion are collected annually from overwintering sites in California and sold throughout America. This practice has been shown to be highly ineffective because of adult dispersal (Dixon 2000, Roy and Majerus, unpubl.). Furthermore, removal of *H. convergens* is considered to have adverse effects on local populations and, in America, is responsible for the distribution of two ladybird parasites (the braconid wasp, *Dinocampus coccinellae* and the microsporidian, *Nosema hippodamiae*) (Saito and Bjornson 2006) and vectoring of plant pathogens (dogwood anthracnose fungus) (Bjornson 2008). This coccinellid has been released in Belgium, Sweden, Denmark, Albania and the Czech Republic in the 1990s and early 2000. It is unknown whether or not it is established.

The use of *H. axyridis* as an augmentative biological control agent (mass reared and released) has been widespread (Berkvens et al. 2008, Brown et al. 2008a). In 1982 it was introduced into France and has since been reared continuously over 100 generations on industrially produced eggs of the moth, *Ephestia kuehniella* (Brown et al. 2008a). It has since been introduced to a number of countries across Europe and also spread to others which had not intentionally released it (Table 8.4.3).

Figure 8.4.7. Larva of *Henosepilachna argus*. Credit: Gilles San Martin

8.4.7 Ecosystems and habitats invaded in Europe by alien Coccinellids

Coccinellid species can be classified as stenotopic or eurytopic (Hodek 1993, Iperti 1991). Microclimate is considered to be a particularly important feature of a coccinellid habitat. Many species of ladybird exhibit a preference for specific vegetation types or certain strata of the habitat. Coupled with this is the requirement for suitable food in sufficient abundance. Habitat preference varies seasonally as the microclimatic characteristics of a habitat change, which in turn influences the distribution of prey populations and the behaviour of coccinellids. Iperti (1999) documents the succession of aphid outbreaks in south eastern France; during a normal year aphids first appear on low plants and shrubs, they then progress to cultivated low plants and early deciduous trees and develop on cultivated trees and shrubs. However, climatic conditions vary annually and so it is difficult to predict the behaviour of coccinellids, particularly in a period of climate change.

There is a strong trend for alien coccinellids to occur in urban or cultivated habitats in Europe. Almost all species are most prevalent in recently cultivated agricultural, horticultural and domestic habitats, gardens and parks and greenhouses (EUNIS categories I I1, I2, J100; see appendix II). *Harmonia axyridis*, the most invasive of the alien coccinellids in Europe, follows this pattern although there have been a considerable number of records in Great Britain from natural habitats (Brown et al. 2008b). Indeed, *H. axyridis* is documented from both woodlands and forest habitats, small anthropogenic woodlands, parks and gardens, agricultural and horticultural habitats as well as from buildings in cities, towns and villages.

The abundance of native and alien coccinellid species in urban habitats and their tendency to aggregate in large numbers during autumn and winter enhances their visibility to people. This aggregation behaviour can be exploited by biological control practitioners through the collection and release of large numbers of beetles but species that exhibit this behaviour, such as *H. axyridis*, are increasingly seen as nuisance insects in domestic dwellings (Roy and Majerus 2006, Roy et al. 2008).

8.4.8 Ecological and economic impacts of alien coccinellids

The ecological and economic impacts of alien coccinellids are not well documented. Many authors have noted the low success rate of coccinellids as biological control agents of aphids (Dixon 2000, Iperti 1999, Majerus et al. 2006a). The success of coccinellids as biological control agents of coccids is higher than that of aphids but still relatively low at only 40 % of cases studied being designated as exerting complete or substantial control (Iperti 1999).

Rodolia cardinalis has been heralded as a success story for biological control (Caltagirone 1989). This species has been introduced into 33 countries to control *I. purchasi* and has yielded complete control in 26 countries (North America, Argentina, Peru, Chile, Portugal, Uruguay, Venezuela, France, Italy, Spain, Greece, Morocco, Tunisia, Turkey, Egypt, India, Japan and New Zealand); substantial control in four countries (Russia, Libya, the Bahamas, Ecuador) and partial control in two countries (Seychelles and Mauritius). A similar rate of success was achieved through the acclimatization of *C. montrouzieri* to control *Pseudococcus* spp. (Iperti 1999). Therefore, *R. cardinalis* and *C. montrouzieri* have contributed economic benefits through the ecosystem service they provide. Indeed, the initial cost of the *R. cardinalis* introduction programme in California 1888 was $1 500 with a return in just over a year of millions of dollars (Majerus 2004).

The lack of success of aphidophagous coccinellids has been attributed to asynchrony between the reproductive and development rates of the predatory coccinellids and their aphid prey (Dixon 2000). Furthermore, many aphidophagous coccinellids, in temperate climates, are univoltine whereas aphids are multivoltine. Coccidophagous coccinellids tend to stay in a localised area throughout their life cycle and, in contrast, aphidophagous coccinellids disperse widely (Iperti 1999).

Most intentional insect introductions do not cause ecological or economic problems, indeed of all the intentionally introduced insects to North America only 1.4 % have caused problems (van Lenteren et al. 2003). Indeed insect introductions are considered to be relatively safe: less than 1 % cause a population level effect in non-targets and only 3–5 % may have caused smaller scale effects (van Lenterenet et al. 2003). However, a number of coccinellids are documented as having non-target effects (van Lenterenet et al. 2003). *Cryptolaemus montrouzieri* is reported to lower the effectiveness of an introduced natural enemy (*Dactylopius opuntiae*) for weed control (Goeden and Louda 1976). The most infamous coccinellid introduction is undoubtedly *H. axyridis* (Majerus et al. 2006b, Roy and Majerus 2006, Roy et al. 2005, Roy and Wajnberg 2008).

Harmonia axyridis has been released as a classical biological control agent in North America since 1916. It has been commercially available in Europe since the 1980s and has many attributes that contribute to its economic viability, including its polyphagous nature. *Harmonia axyridis* preys on a wide variety of tree-dwelling homopteran insects, such as aphids, psyllids, coccids, adelgids and other insects (Koch et al. 2006). In North America, as well as offering effective control of target pests, such as aphids in pecans (Tedders and Schaefer 1994), *H. axyridis* is also providing control of pests in other systems such as *Aphis spiraecola* in apple orchards (Brown and Miller 1998) and several citrus pests (Michaud 2002). In both Asia and North America, *H. axyridis* has been reported to contribute to control of aphids on sweet corn, alfalfa, cotton, tobacco, winter wheat and soybean (Longo et al. 1994). The spread and increase of *H. axyridis* throughout Europe could, therefore, prove to be beneficial to ecosystem services through the reduction in aphid numbers below economically damaging levels and subsequent reduction in the use of chemical pesticides.

The polyphagous nature of *H. axyridis* means that negative impacts on non-target prey species would appear to be inevitable (Majerus 2006, Pell et al. 2008). However, there is very limited empirical evidence on this subject and studies considering the effects of *H. axyridis* on the population demography of non-target aphids, coccids and other prey species away from crop systems have not been conducted. *Harmonia axyridis* has been implicated as a potential predator of immature monarch butterflies, *Danaus plexippus*, an aposematic species that contains defensive chemicals (Koch et al. 2003). Laboratory studies have also indicated the potential for *H. axyridis* to engage in intra-guild predation (Pell et al. 2008, Roy et al. 2008, Ware and Majerus 2008). It is likely that many other species will be directly or indirectly affected by the arrival of *H. axyridis*. Indeed, intraguild predation is thought to be an important force in structuring aphidophagous ladybird guilds (Yasuda et al. 2004) and so *H. axyridis* has the potential to dramatically disrupt native guilds in Europe. *Harmonia axyridis* is a large, aggressive, polyphagous coccinellid (with a tendency for intraguild predation) that could impact on the abundance of native coccinellids and reduce their available niches (Legaspi et al. 2008).

The wide dietary range of *H. axyridis* coupled with its ability to disperse rapidly, forage widely and continuously breed gives this species the potential to significantly reduce European populations of coccids and aphids. This is, of course, considered beneficial in crop and horticultural systems, but not in other habitats where such direct competition for prey may result in a reduction in biodiversity and declines in native beneficial predators and parasitoids of aphids and coccids (Majerus 2006).

Majerus et al. (2008) noted that the negative effects of *H. axyridis* on other aphidophages are likely to be the result of a complex range of interactions, with *H. axyridis* in general having a competitive edge through resource competition, intraguild predation and a more plastic phenotype. A more rapid development rate, continual breeding ability and lack of diapause requirement, efficient chemical defence and relatively large size would provide *H. axyridis* with a significant reproductive advantage over many native British species. The pattern is anticipated to be widespread throughout Europe (Brown et al. 2008a).

8.4.10 Conclusions

Coccinellids have been introduced widely throughout Europe for the biological control of pest insects. Some of these species have established and for others the status is unknown. It is difficult to estimate the proportion of alien coccinellids in Europe for two reasons: there is not a definitive European check list for coccinellids and the status of some of the alien species is unknown. However, the proportion of alien coccinellids appears to be higher (approximately 5–10 %) than the proportion of aliens for other taxonomic groups (3.1 % alien Diptera). Only one species (*H. axyridis*) is considered to be invasive.

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References

Adriaens T, Branquart E, Maes D (2003) The Multicoloured Asian Ladybird *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae), a threat for native aphid predators in Belgium? *Belgian Journal of Zoology* 133: 195–196.

Adriaens T, San Martin y Gomez G, Maes D (2008) Invasion history, habitat preferences and phenology of the invasive ladybird *Harmonia axyridis* in Belgium. *Biocontrol* 53: 69–88.

Audisio P, Canepari C (2009) Fauna Europaea - Coccinellidae. http://www.faunaeur.org/full_results.php?id=11062.

Belicek J (1976) Coccinellidae of Western Canada and Alaska with analyses of the transmontane zoogeographic relationship between the fauna of british Columbia and Alberta. *Questiones Entomology*: 283–409.

Berkvens N, Bonte J, Berkvens D, Tirry L, De Clercq P (2008) Pollen as an alternative food for *Harmonia axyridis*. *Biocontrol* 53: 201–210.

Berthiaume R, Hébert C, Cloutier C (2007) Comparative use of Mindarus abietinus (Homoptera: Aphididae) by two coccinellids (Coleoptera: Coccinellidae), the native Anatis mali and the exotic Harmonia axyridis, in a Christmas tree plantation. *Environmental Entomology* 36: 319–328.

Bjornson S (2008) Natural enemies of the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville: Their inadvertent importation and potential significance for augmentative biological control. *Biological Control* 44: 305–311.

Booth RG (1998) A review of the species resembling *Chilocorus nigrita* (Coleoptera: Coccinellidae): potential agents for biological control. *Bulletin of Entomological Research* 88: 361–367.

Booth RG, Cross AE, Fowler SV, Shaw RH (1995) The biology and taxonomy of *Hyperaspis pantherina* (Coleoptera: Coccinellidae) and the classical biological control of its prey, *Orthezia insignis* (Homoptera: Ortheziidae). *Bulletin of Entomological Research* 85: 307–314.

Borges I, Soares AO, Hemptinne JL (2006) Abundance and spatial distribution of aphids and scales select for different life histories in their ladybird beetle predators. *Journal of Applied Entomology* 130: 356–359.

Brown MW, Miller SS (1998) Coccinellidae (Coleoptera) in apple orchards of eastern West Virginia and the impact of invasion by *Harmonia axyridis*. *Entomological News* 109: 143–151.

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, Hagg T, Kenis M, Klausnitzer BEM, Kovář I, Loomans AJ, Majerus MEN, Nedved O, Pedersen J, Rabitsch W, Roy HE, Ternois V, Zakharov I, Roy DB (2008a) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *Biocontrol* 53: 5–21.

Brown PMJ, Roy HE, Rothery P, Roy DB, Ware RL, Majerus MEN (2008b) *Harmonia axyridis* in Great Britain: analysis of the spread and distribution of a non-native coccinellid. *Biocontrol* 53: 55–67.

Caltagirone L E (1989) The history of the vedalia beetle importation to California and its impact on the development of biological control. *Annual Review of Entomology* 34: 1–16.

De Clercq P, Bonte M, Van Speybroeck K, Bolckmans K, Deforce K (2005) Development and reproduction of *Adalia bipunctata* (Coleoptera: Coccinellidae) on eggs of *Ephestia kuehniella* (Lepidoptera: Phycitidae) and pollen. *Pest Management Science* 61: 1129–1132.

Dixon A FG (2000) *Insect predator-prey dynamics: Ladybeetles and Biological Control*. Cambridge: Cambridge University Press. 257 pp.

Erler F, Tunc I (2001) A survey (1992–1996) of natural enemies of Diaspididae species in Antalya, *Turkey. Phytoparasitica* 29: 299–305.

Fowler S V (2004) Biological control of an exotic scale, *Orthezia insignis* Browne (Homoptera: Ortheziidae), saves the endemic gumwood tree, *Commidendrum robustum* (Roxb.) DC. (Asteraceae) on the island of St. Helena. *Biological Control* 29: 367–374.

Frank J H, McCoy ED (2007) The risk of classical biological control in Florida. Biological Control 41: 151–174.

Fürsch H (1990) Taxonomy of coccinellids, corrected version. *Coccinella* 2: 4–6.

Galecka B (1991) Distribution and role of coccinellids in an agricultural landscape. In: Polgar L, Chambers RJ, Dixon AFG, Hodek I (Eds) *Behaviour and Impact of Aphidophaga*. The Hague : SPB Academic Publishing, 137–141.

Goeden RD, Louda SM (1976) Biotic interference with insects imported for weed control. *Annual Review of Entomology* 21: 325–342.

Gurney B, Hussey NW (1970) Evaluation of some coccinellid species for biological control of aphids in protected cropping. *Annals of Applied Biology* 65: 451–458.

Hamid HA, Michelakis S (1994) The importance of *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) in the control of the citrus mealy bug *Planococcus citri* (Risso) (Hom.: Coccoidea) under specific conditions. *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 118: 17–22.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw M, Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England*. Peterborough, UK: English Nature. 82 pp.

Hodek I (1993) Habitat and food specificity in aphidophagous predators. *Biocontrol Science and Technology* 3: 91–100.

Hodek I (1996) Food Relationships. In: Hodek I, Honek A (Eds) *Ecology of Coccinellidae*. The Hague: Kluwer Academic Publishers, 143–238.

Humble LM (1994) Recovery of additional exotic predators of balsam woolly adelgid, *Adelges piceae* (Ratzeburg) (Homoptera, Adelgidae), in British Columbia. *Canadian Entomologist* 126: 1101–1103.

Iperti G (1991) Abiotic and biotic factors influencing the distribution of the aphidophagous coccinellidae. In: Polgar L, Chambers RJ, Dixon AFG, Hodek I (Eds) *Behaviour and Impact of Aphidophaga*. The Hague: SPB Academic Publishing, 163–166.

Iperti G (1999) Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture Ecosystems & Environment* 74: 323–342.

Izhevsky SS, Orlinsky AD (1988) Life history of the importaed *Scymnus (Nephus) reunioni* (Col.: Coccinellidae) predator of mealybugs. *Entomophaga* 33: 101–114.

Katsoyannos P (1997) Status and importance of *Rhyzobius forestieri* (Col.: Coccinellidae) on citrus at Chios island, Greece, nine years after its introduction. *Entomophaga* 42: 387–392.

Koch RL, Hutchison WD, Venette RC, Heimpel GE (2003) Susceptibility of immature monarch butterfly, *Danaus plexippus* (Lepidoptera: Nymphalidae: Danainae), to predation by *Harmonia axyridis* (Coleoptera: Coccinellidae). *Biological Control* 28: 265–270.

Koch RL, Venette RC, Hutchison WD (2006) Invasions by *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in the Western Hemisphere: Implications for South America. *Neotropical Entomology* 35: 421–434.

Kovář I (1996). Phylogeny. In: Hodek I, Honek A (Eds) *Ecology of Coccinellidae*. The Hague: Kluwer Academic Publishers, 19–32.

Kutuk H, Yigit A (2007) Life table of *Delphastus catalinae* (Horn) (Coleoptera: Coccinellidae) on cotton whitefly, *Bemisla tabaci* (Genn.) (Homoptera: Aleyrodidae) as prey. *Journal of Plant Diseases and Protection* 114: 20–25.

Legaspi JC, Legaspi BC, Simmons AM, Soumare M (2008) Life table analysis for immatures and female adults of the predatory beetle, *Delphastus catalinae*, feeding on whiteflies under three constant temperatures. *Journal of Insect Science* 8: 07.

Longo S, Mazzeo G, Russo A, Siscaro G (1994) *Aonidiella citrina* (Coquillet) a new pest of citrus in Italy. *Informatore Fitopatologico* 44: 19–25.

Majerus M, Strawson V, Roy HE (2006a) The potential impacts of the arrival of the harlequin ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), in Britain. *Ecological Entomology* 31: 207–215.

Majerus MEN (1994). *Ladybirds*. Somerset: Harper Collins Publisher.

Majerus MEN (2006a) The impact of male-killing bacteria on the evolution of aphidophagous coccinellids. *European Journal of Entomology* 103: 1–7.

Majerus MEN, Roy HE, Brown PMJ, Ware RL (2006b) Guide to Ladybirds of the British Isles. Shrewsbury: Field Studies Council.

Majka CG, McCorquodale DB (2006) The Coccinellidae (Coleoptera) of the Maritime Provinces of Canada: new records, biogeographic notes, and conservation concerns. *Zootaxa* 1154: 49–68.

Malausa JC, Franco E, Brun P (1988) Establishment on the Cote-Dazur and in Corsica of *Serangium parcesetosum* (Col.: Coccinellidae), a predator of the citrus whitefly, *Dialeurodes citri* (Hom.: Aleyrodidae). *Entomophaga* 33: 517–519.

Michaud JP (2002) Invasion of the Florida citrus ecosystem by *Harmonia axyridis* (Coleoptera: Coccinellidae) and asymmetric competition with a native species, *Cycloneda sanguinea*. Environmental Entomology 31: 827–835.

Obrycki JJ, Kring TJ (1998) Predaceous Coccinellidae in biological control. *Annual Review of Entomology* 43: 295–321.

Pell JK, Baverstock J, Roy HE, Ware RL, Majerus MEN (2008) Intraguild predation involving *Harmonia axyridis*: a review of current knowledge and future perspectives. *Biocontrol* 53: 147–168.

Phoofolo MW, Giles KL, Elliott NC (2008) Larval life history responses to food deprivation in three species of predatory lady beetles (Coleoptera: Coccinellidae). *Environmental Entomology* 37: 315–322.

Ponsonby DJ, Copland MJW (2007a) Aspects of prey relations in the coccidophagous ladybird *Chilocorus nigritus* relevant to its use as a biological control agent of scale insects in temperate glasshouses. *Biocont*rol 52, 629–640.

Ponsonby DJ, Copland MJW (2007b) Influence of host density and population structure on egg production in the coccidophagous ladybird, *Chilocorus nigritus* F. (Coleoptera: Coccinellidae). *Agricultural and Forest Entomology* 9: 287–296.

Ricci C, Primavera A, Negri V (2006) Effects of low temperatures on *Chilocorus kuwanae* (Coleoptera: Coccinellidae) trophic activity. *European Journal of Entomology* 103: 547–551.

Roy HE, Majerus MEN (in press). *Coccinellids in a Changing World*. In Kindlmann P (Ed.) *Aphids in the changing world: Patterns and processes*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Roy HE, Majerus MEN (2006) *Harmonia axyridis*: A successful biocontrol agent or an invasive threat? In: Eilenberg J, Hokkanen HMT (Eds) *An ecological and societal approach to biological control*. Dordrecht, The Netherlands: Kluwer Academic Publishers, 295–309.

Roy HE, Brown PMJ, Rowland F, Majerus MEN (2005) Ecology of *Harmonia axyridis*. *British Wildlife* 16: 403–407.

Roy HE, Brown PMJ, Ware RL, Michie L-J, Beckmann B, Majerus MEN (2008) The harlequin ladybird marches on. *British Wildlife* 19: 182–186.

Roy HE, Wajnberg E (2008). From biological control to invasion: the ladybird *Harmonia axyridis* as a model species. *Biocontrol* 53: 1–4.

Saito T, Bjornson S (2006) Horizontal transmission of a microsporidium from the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville (Coleoptera: Coccinellidae), to three coccinellid species of Nova Scotia. *Biological Control* 39: 427–433.

Simmons AM, Legaspi JC (2004) Survival and predation of *Delphastus catalinae* (Coleoptera: Coceinellidae), a predator of whiteflies (Homoptera: Aleyrodidae), after exposure to a range of constant temperatures. *Environmental Entomology* 33: 839–843.

Simmons AM, Legaspi JC (2007). Ability of *Delphastus catalinae* (Coleoptera: Coccinellidae), a predator of whiteflies (Homoptera: Aleyrodidae), to survive mild winters. *Journal of Entomological Science* 42: 163–173.

Smith SF, Krischik VA (2000) Effects of biorational pesticides on four coccinellid species (Coleoptera: Coccinellidae) having potential as biological control agents in interior landscapes. *Journal of Economic Entomology* 93: 732–736.

Tedders WL, Schaefer PW (1994) Release and establishment of *Harmonia axyridis* (Coleoptera: Coccinellidae) in the south-eastern United States. *Entomological News* 105: 228–243.

Thomas RJ, Majerus MEN, Brown PMJ, Roy HE (2009) A first record of *Cynegetis impunctata* (Coleoptera: Coccinellidae). *British Journal of Entomology and Natural History* 21

van Lenteren JC, Babendreier D, Bigler F, Burgio G, Hokkanen HMT, Kuske S, Loomans A JM, Menzler-Hokkanen I, van Rijn PCJ Thomas MB, Tommasini MG, Zeng QQ (2003). Environmental risk assessment of exotic natural enemies used in inundative biological control. *Biocontrol* 48: 3–38.

van Lenteren JC, Bale J, Bigler F, Hokkanen HMT, Loomans AJM (2006) Evaluating risks of releasing exotic biological control agents of arthropod pests. *Annual Review of Entomology* 51: 609–634.

Ware RL, Majerus MEN (2008) Intraguild predation of immature stages of British and Japanese coccinellids by the invasive ladybird *Harmonia axyridis*. *Biocontrol* 53: 169–188.

Yasuda H, Evans EW, Kajita Y, Urakawa K, Takizawa T (2004) Asymmetric larval interactions between introduced and indigenous ladybirds in North America. *Oecologia* 141: 722–731.

Yigit A, Canhilal R (2005) Establishment and dispersal of *Serangium parcesetosum* Sicard (Coleoptera, Coccinellidae), a predatory beetle of citrus whitefly, *Dialeurodes citri* Ashm. (Homoptera, Aleyrodidae) in the East Mediterranean region of Turkey. *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection* 112: 268–275.

Yigit A, Canhilal R, Ekmekci U (2003). Seasonal population fluctuations of *Serangium parcesetosum* (Coleoptera: Coccinellidae), a predator of citrus whitefly, *Dialeurodes citri* (Homoptera: Aleyrodidae) in Turkey's eastern Mediterranean citrus groves. *Environmental Entomology* 32: 1105–1114.

Zang LS, Liu TX (2007) Intraguild interactions between an oligophagous predator, *Delphastus catalinae* (Coleoptera: Coccinellidae), and a parasitoid, *Encarsia sophia* (Hymenoptera: Aphelinidae), of *Bemisia tabaci* (Homoptera: Aleyrodidae). *Biological Control* 41: 142–150.

Table 8.4.1. List and main characteristics of the Coccinellidae species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Phylogeny after (2 0, 35). Last update 01/03/2010.

Subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Coccidulinae								
Rhyzobius forestieri (Mulsant, 1853)	A	Parasitic/ Predator	Australasia	1982, IT	AL, FR, GR, IT	I	Coccids (Scale insects)	Katsoyannos (1997)
Rhyzobius lophanthae (Blaisdell, 1892)	A	Parasitic/ Predator	Australasia	1908, IT	AL, DE, ES, ES-BAL, FR, FR-COR, GB, GR,GR-CRE, IT, IT-SAR, IT-SIC, IL, MT, PT, PT-AZO, PT-MAD,	I, J100	Coccids (Scale insects specifically Diaspididae)	Erler (2001)
Rodolia cardinalis (Mulsant, 1850)	A	Parasitic/ Predator	Australasia	1888, PT	AL, CH, CY, DE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, UA	I, J100	Coccids (Scale insects)	Caltagirone (1989), Frank and McCoy (2007)
Scymninae								
Hyperaspis pantherina Fürsch, 1975	A	Parasitic/ Predator	Africa	2002, PT-MAD	PT-MAD	U	*Orthezia insignis* (Scale insect)	Booth et al. (1995), Fowler (2004)
Cryptolaemus montrouzieri Mulsant, 1853	A	Parasitic/ Predator	Australasia	1908, IT	AL, ES, ES-CAN, FR, FR-COR, GR,GR-CRE, IL, IT, IT-SAR, IT-SIC, PT, RU, SE,	I, J100	Mealybugs	Hamid and Michelakis (1994), Smith and Krischik (2000)
Nephus reunioni Fürsch, 1974	A	Parasitic/ Predator	Africa	1983, FR	AL, ES, FR, GR, IT-SAR, PT	I	Coccids (Scale insects)	Izhevsky and Orlinsky (1988)
Chilocorinae								
Chilocorus kuwanae Silvestri, 1909	A	Parasitic/ Predator	Asia	1989, IT	AL, IT	I	Coccids (Scale insects)	Ponsonby and Copland (2007b), Ricci et al. (2006)
Chilocorus nigritus (Fabricius, 1798)	A	Parasitic/ Predator	Asia	1994, IT	AL, ,IT	I, J100	Coccids (Scale insects)	Booth (1998), Ponsonby and Copland (2007a), Ponsonby and Copland (2007b)

Subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sticholotidinae								
Serangium parcesetosum Sicard, 1929	A	Parasitic/ Predator	Asia	1986, FR-COR	FR, FR-COR	I	Aleyrodidae	Yigit and Canhilal (2005), Yigit et al. (2003)
Coccinellinae								
Harmonia axyridis (Pallas, 1773)	A	Parasitic/ Predator	Asia	1991, BE	AL, AT, BE, BG, BY, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, GR-ION, GR-SEG, HU, IL, IT, IT-SIC, , LI, LU, NL, NO, PT, RO, RU, SE, SK, UA	I	Polyphagous insect predator particularly aphids and coccids	Adriaens et al. (2003), Adriaens et al. (2008), Brown et al. (2008a), Brown et al. (2008b), Koch et al. (2003), Majerus (1994), Roy et al. (2005), Roy and Wajnberg (2008)
Hippodamia convergens Guerin-Meneville, 1842	A	Parasitic/ Predator	North America	1992, CZ	AL, BE, CZ, DK, SE	FA, J100	Aphids	Bjornson (2008), Phoofolo et al. (2008), Saito and Bjornson (2006)

Table 8.4.2. List and main characteristics of the Coccinellidae species alien within Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Phylogeny after Fürsch (1990), Koch et al. (2006). Last update 01/03/2010.

SubFamily *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Scymninae						
Scymnus impexus Mulsant, 1850*	Parasitic/ Predator	West Palearctic	GB, SE	G, I2	*Dreyfusia piceae* on spruce and fir	Humble (1994), Majka and McCorquodale (2006)
Epilachninae						
Henosepilachna argus (Geoffroy, 1762)*	Phyto-phagous	West Palearctic	GB	E5, I2, FA	White bryony (*Bryonia dioica*)	Hill et al. (2005)

Table 8.4.3. Summary of release dates and records from wild populations of *Harmonia axyridis* across Europe. Adapted from Brown et al. (2008a). Updated: 01/03/2010

Country	**Year of release (blank if not released)**	**Year of first record in the wild**
Ukraine	1964	Unknown
Belarus	1968	Unknown
Portugal	1984	
France	1982	1991
Greece	1994	1998
Germany	1997	1999
Belgium	1997	2001
Netherlands	1996	2002
Spain	1995	2003
Switzerland	1996	2004
Luxembourg		2004
England and Channel Isl.		2004
Italy	1990s	2006
Czech Republic	2003	2006
Austria		2006
Denmark	2000s	2006
Wales		2006
Norway		2006
Poland		2007
Liechtenstein		2007
Sweden		2007
Northern Ireland		2007
Scotland		2007
Serbia		2008
Slovakia		2008
Hungary		2008
Bulgaria		2009
Romania		2009

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Coleoptera families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae Chapter 8.5

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Abstract

Here we consider 274 alien Coleoptera species belonging to 41 of the 137 beetle families in Europe (Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae are treated separately elsewhere). Among the families we consider as having invaded the European fauna, Acanthocnemidae and Ptilodactylidae represent new arrivals. Many species-rich families have surprisingly few aliens, whereas some relatively minor families such as Dermestidae, Nitidulidae and Anobiidae have a relatively high representation of alien species. Since the start of the 19th century, the number of coleopteran aliens introduced into Europe has continued to increase. Alien species colonizing Europe derive from a wide range of geographic regions as well as ecozones, but the most important source area is Asia. The countries with the largest number of alien species established are France, Germany and Italy. The majority have been introduced accidentally via international transport mechanisms. The most important route for importation is stored products and crops, followed by transport of wood, then horticultural and ornamental plants. Most alien species in these families are found within anthropogenic habitats in Europe. The introduction of invasive alien beetles in these families has had significant economic impacts, particularly as pests of stored foodstuffs, as well as serious ecological impacts. For example, the buprestid species *Agrilus planipennis*, recently recorded in Russia, is an important potential economic threat which may also impact the biodiversity associated with ash trees.

Keywords

Europe, beetles, Dermestidae, Nitidulidae, Anobiidae, alien species, invasive species, stored products, pests

8.5.1. Introduction

Introductions of alien species in Europe started in ancient times (Genovesi and Shine 2003), but this phenomenon has grown rapidly during the two last centuries. This is considered largely to be a consequence of the globalization of trade (Smith et al. 2007). Among these introductions, Coleoptera dominate the alien terrestrial invertebrates in Europe, where the fauna consists of over 27,000 species in 137 families (Fauna Europaea Web Service). In addition to the alien species observed in the families Cerambycidae, Curculionidae (*sensu lato*), Chrysomelidae (*sensu lato*) and Coccinelidae, which were treated in the preceding chapters, 274 other beetles of exotic or cryptogenic origin have been established to date in Europe (Table 8.5.1). These alien species belong to 41 different families. Additionally, 237 species are considered to have been introduced through human activity from one region of Europe to another (Table 8.5.2). However, the cause of such movements are often difficult to ascertain, particularly where the original range is poorly known. Thus, the analyses detailed below will mostly consider the species alien *to* Europe.

8.5.2 Diversity of alien coleopteran species

The Coleoptera families treated here with the greatest number of species in Europe are Staphylinidae (rove beetles), Carabidae (ground beetles) and Tenebrionidae (darkling beetles) but these have proportionally few alien species (figure 8.5.1). These three families constitute an important component of the European ground fauna (Dajoz 2002). Conversely, the families with the most aliens in Europe and significant economic impact tend to be families with relatively few native species such as Dermestidae (carpet beetles), Nitidulidae (sap-feeding beetles) and Anobiidae (death-watch beetles). Two of the 41 families do not have any native species in Europe and they are new arrivals for the European fauna: Acanthocnemidae (little ash beetles) and Ptilodactylidae (toe-winged beetles). The following presentation of families follows the taxonomic classification of Fauna Europaea (Fauna Europaea Web Service) and of the Tree of Life Web Project (Maddison et al. 2007) (for Ptilodactylidae, not included in Fauna Europaea).

ADEPHAGA

The **Carabidae,** are widespread and known to colonize a great diversity of ecological niches (Denux et al. 2007, Holland 2002). They are typically predators (as larvae and adults), although some groups (e.g. Harpalinae) have evolved toward granivory (feeding on seeds). These life traits do not favour passive transportation by humans, and thus, only eight alien species have been established in Europe, accounting for approximately 0.2% of the European carabid fauna. Among these, *Somotrichus unifasciatus*, *Trechicus nigriceps* and *Plochionus pallens* have benefited from the global trade in food products to become cosmopolitan, being introduced with cargos of groundnuts, rice, broad beans,

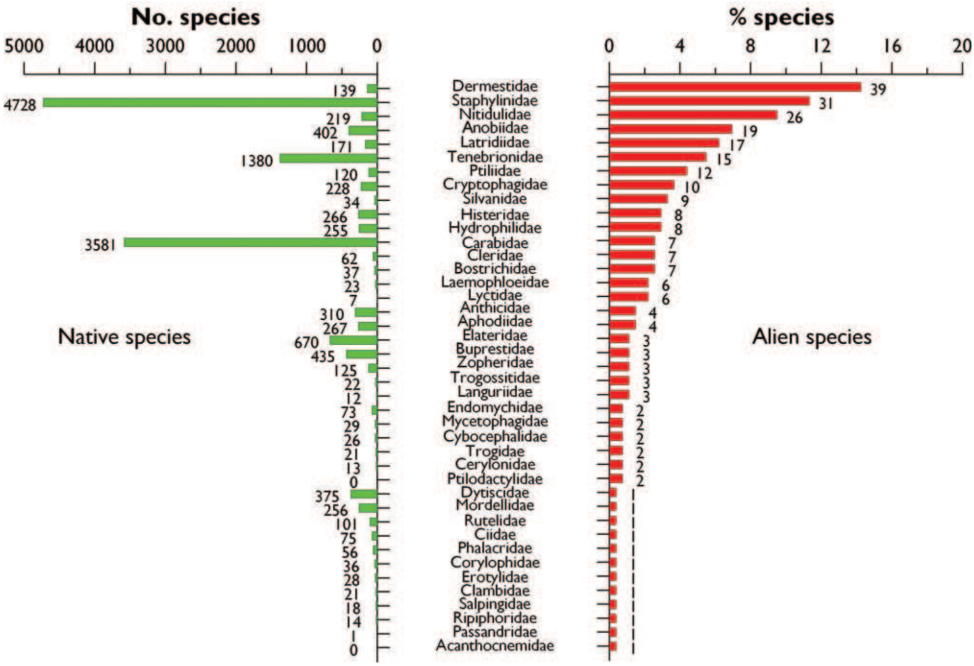

Figure 8.5.1. Relative importance of the Coleoptera families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae families in the alien and native fauna in Europe. *Right* - Relative importance of the families in the alien entomofauna. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of alien species observed per family. *Left* - Species richness of the same families in the native European entomofauna. The number over each bar indicates the total number of species observed per family in Europe.

cocoa, etc. (Jeannel 1942, Weidner et al. 1984). Only one species is established throughout Europe: *Trechicus nigriceps* (recorded in 30 countries). This species seems to have been imported from the Eastern coast of Africa several centuries ago (Jeannel 1942).

The **Dytiscidae** (predaceous diving beetles) are all aquatic carnivores. Only one dytiscid beetle has been reported in our database (DAISIE). This large South American species, *Megadytes costalis*, has been recorded once in Great Britain, but there is no data on its establishment in the wild.

POLYPHAGA STAPHYLINIFORMIA

The **Hydrophilidae** (water scavenger beetles) are another family of aquatic beetles, easily distinguished from the Dytiscidae by the length of their maxillary palpi. One tribe, the Sphaeridiini, is exceptional due to its terrestrial, saprophagous and coprophagous habits. Many species share mammal dung with scarab beetles. Significantly, among eight hydrophilids reported as aliens in Europe, seven belong to the Sphaeridiini.

The **Histeridae** (clown beetles) are mainly predators, specializing on saprophagous, coprophagous or necrophagous prey. Eight species have been reported in the database, but little is known about their life traits, except for the widespread, cryptogenic *Carcinops pumilio*, which is common everywhere in natural and anthropized habitats.

The **Ptiliidae** (featherwinged beetles) are a very small family (120 species in Europe and 180 in the world) of which 12 alien species have been recorded in Europe. These are very tiny beetles, including the smallest of all, with a length of just 0.5 mm, whilst even the largest members of the family do not exceed 2 mm. Adults and larvae are usually found in rotting organic material in a wide range of habitats. Their small size and lifestyle means that they are easily dispersed via the movements of soil.

Staphylinidae is the most important group of Coleoptera in Europe and the second richest in the world (with over 46,000 species), but the number of alien species (31) in Europe is proportionally low, representing 0.7% of the whole of the Europeans staphylinid fauna. Many genera were not included in Fauna Europaea (Fauna Europaea Web Service), due to the lack of taxonomic expertise. Staphylinidae alien species found in Europe are essentially predatory (Coiffait 1972, Paulian 1988) and mainly species associated with compost, humus and decomposing matter (Cho 2008, Ødegaard and Tømmerås 2000, Tronquet 2006), such as *Bisnius parcus*, *Lithocharis nigriceps* and *Oxytelus migrator*. One predatory species, *Philonthus rectangulus*, has been reported from 36 countries/islands. Originating from temperate East Asia, it may have expanded westward naturally.

POLYPHAGA SCARABAEIFORMIA

The **Trogidae** (hide beetles) are a small family of beetles related to the scarabs. They feed on mammal skins and furs, or on bird feathers, either as late arriving necrophages on carrion, or as commensals of vertebrates in their nests. Two species from Australasia have been recorded in Spain in our database.

The **Aphodiidae** (dung beetle) are mainly small dung beetles, frequently included in the Scarabaeidae. Four species have been recorded as aliens, in one country only. Both *Saprosites* species introduced in Great Britain seem to be saproxylic beetles (Angus et al. 2003).

The **Rutelidae** (leaf chafers) are a family of brightly-coloured beetles, especially diverse in the tropics. Only one species of this family has been found in the Azores, the well-known Japanese beetle, *Popilia japonica*, which is considered as a severe pest in the United States, where it was introduced from Japan in 1912.

POLYPHAGA ELATERIFORMIA

The **Clambidae** (minute beetles) are very small beetles that have the capability to roll into a ball. One species is listed here, the Australian *Clambus simsoni*, a saprophagous species which seems to be rapidly expanding in western Europe.

The **Buprestidae** (metallic wood-boring or jewel beetles) are a well-known family of xylophagous beetles. In most cases, the larvae develop in living wood, and a few species became major pests in orchards or forests. Only three buprestid species have been reported as aliens in the database, each observed in only one country.

The **Ptilodactylidae**, the "toed-winged beetles", are a group of elateriform Coleoptera, which was formely treated as part of the Dascilloidea and included in Byrrhoidea (Maddison et al. 2007). Little is known of the biology of adults (Aberlenc and Allemand 1997). The habit of soil-leaf litter dwelling of both the adults and larvae facilitates their distribution with potted plants (Mann 2006).

The **Elateridae** (click beetles) are a large family of beetles with quite diverse life history traits. Some species have soil-living larvae, either predators or rhizophages, with reported agricultural pests in the latter category. Other species are saproxylic (predators or saprophages), some of which are very specialized, and have high conservation value. Three species are reported as aliens here, occuring in one country each. The life history traits of these species remain unknown.

POLYPHAGA BOSTRICHIFORMIA

The European **Dermestidae** comprise only 139 species (less than 1% of the European Coleoptera fauna) yet they are the largest contributor to the database, with 40 species reported as aliens. Many species are synanthropic and associated with animal remains, leathers and skins, dried meats, woollens and furs (Delobel and Tran 1993), such as *Dermestes vorax*, *D. frischi*, *D. maculatus*, *D. lardarius* and *Anthrenus flavidus*. Some species eat stored seeds such as *Trogoderma granarium.* The protraction of the number of larval stages and longevity in suboptimal nutritive media (Delobel and Tran 1993), as well as the relevance of the food product trade, explain partly how the damaging pests of this family have easily conquered new territories.

The **Lyctidae** (true powder-post beetles) are a very small family (13 species in Europe) closely related to the Bostrichidae. All species are wood-borers, specializing on hardwoods. They usually attack dry wood that is less than five years old, and may become important pests of structural wood or furniture. As inhabitants of raw or manufactured wood products, they are easily transported. Six species have been reported as aliens in Europe, but only one, *Lyctus brunneus*, has been established throughout the continent for more than 150 years.

The **Bostrichidae** (horned powder-post beetles) are a small family (37 native species in Europe). The native species are saproxylophages, whereas the aliens are either wood-borers or grain-feeders (apparently, some species show both feeding habits) (Lesne 1901). Seven species have been reported as aliens, and have been found in many countries. The wood-borers may cause important damage to manufactured objects, but the stored-product feeders (*Dinoderus* spp., *Rhyzopertha dominica*) are the most economically harmful. Among these, the lesser grain borer, *Rhyzopertha dominica*, has been observed in 34 countries/islands.

The **Anobiidae** have 19 alien species compared to 402 native species in Europe. About 11 species are associated with stored food products and include devastating pests such as *Lasioderma sericorne* which attacks a wide variety of dried products of animal or vegetable origin (Espanol 1992, Weidner et al. 1984). Several species attack soft woody matter: wood in the case of *Ernobius mollis*, but also books in the case of *Nicobium castaneum*, which can cause irrepairable damage. Many cryptogenic anobiid species are established in Europe for centuries, and may be found in many countries.

POLYPHAGA CUCUJIFORMIA

The **Nitidulidae** have 26 aliens compared with 219 native species in Europe. A third of these have occurred as far west as Macaronesia, but the other species have expanded their range in many countries of mainland Europe. As the majority of species are pollen-eaters, phytophagous, mycetophagous or predatory, they have a particular agronomic importance, damaging crops and stored food products. Among these, the 13 aliens species of the genus *Carpophilus* cause damage to dried fruits (Weidner et al. 1984).

The **Cybocephalidae** are a very small family, frequently subsumed within Nitidulidae. Cybocephaline beetles are well known predators of armoured scale insects (Coccoidea: Diaspididae) throughout tropical, sub-tropical and temperate regions of the world (Kirejtshuk et al. 1997).They are minute beetles, very convex and able to roll into a ball, as for Clambidae.

The **Silvanidae** (silvanid flat bark beetles) are a small family (34 native species in Europe) of flat beetles, formerly included in the Cucujidae. These insects were originally mycetophages, living under the bark of trees, but the feeding habits of many species have adapted to grain and fruit feeding, so that they have become synanthropic pests of stored products (Ratti 2007). Nine species are listed in the database, among which three are cryptogenic, long-established species occuring in several countries, such as the sawtoothed grain beetle, *Oryzaephilus surinamensis*.

The **Laemophloeidae** (lined flat bark beetles) are a small family of flat beetles with 23 native species in Europe, which was formerly included in the Cucujidae. They are closely related to the Silvanidae, and show the same life history traits. Six species, belonging to the genus *Cryptolestes*, are reported as aliens in Europe. They have established successfully in many countries.

The **Phalacridae** (shining flower beetles) are a small family of minute, rounded beetles. One North American species of *Phalacrus* has been recorded in the Azores, whose biological traits remain unknown (many species are micro-mycetophages).

The **Cryptophagidae** (silken fungus beetles) are an important family of mycetophagous insects with 228 native species in Europe, living in various habitats. Ten species have been reported as aliens in Europe, which are now established in many countries (the Cryptophagidae have the widest species range). The majority of these species (*Cryptophagus* spp.) are cryptogenic, feeding on fungal spores or decaying vegetal material, sometimes on stored products.

The **Languriidae** (lizard beetles) are a small family (12 native species in Europe) of phytophagous or saprophagous beetles. Three alien species are considered here, with a rather low dispersal rate. Nevertheless, *Cryptophilus integer* and *Pharaxonotha kirschii* are reported as pests of stored products.

The **Erotylidae** (pleasing fungus beetles) are a small family of mycetophagous beetles, with many species in saproxylic habitats. One Japanese species, *Dacne picta*, has possibly been introduced in Central Europe.

The **Cerylonidae** (minute bark beetles) are a small family of saproxylic beetles. They just appear here because a well-known pest of stored grain, *Murmidius ovalis*, is now included in this family (formerly Murmidiidae). This is a cosmopolitan species probably originating from tropical Asia.

The **Endomychidae** (handsome fungus beetles) are a small family of mycetophagous beetles (Shockley 2009, Shockley et al. 2009b), closely related to the Coccinellidae. Two very small species (*Holoparamecus* spp.) are cryptogenic and may be found in many countries worldwide.

The **Corylophidae** (minute hooded beetles) are another small family of micromycetophagous beetles, which occur in a variety of habitats. One species, *Orthoperus aequalis*, from Australia, has now established in 10 countries within Europe.

The **Latridiidae** (minute hooded beetles) are also a small family with 171 native species in Europe and 17 aliens which are essentially mycetophagous and associated with stored food products, such as *Dianerella filum* or *Cartodere nodifer*. These species are also plaster beetles which occupy wet places in the plastered walls of houses (Bouget and Vincent 2008). However, these latridiids do not appear to have an economic impact (Delobel and Tran 1993) and merely indicate bad food storage conditions.

The **Trogositidae** (bark-gnawing beetles) are a small family of saproxylic insects, living as saprophages or predators of other insects under the bark of trees. The three species reported here are predators of cosmopolitan pests of stored products.

The **Cleridae** (checkered beetles) are a conspicuous family of brightly coloured insects. Nearby all species are predators of other insects. Seven species are reported as aliens in the database, some of them (*Necrobia* spp.) established in Europe for a long time. These are either predators of xylophagous beetles or predators of stored product insects, and thus likely to be transported everywhere with their prey. We include here in the Cleridae the small family Thanerocleridae, which shows life traits similar to the typical Cleridae, with one introduced species, *Thaneroclerus buqueti*.

The **Acanthocnemidae**, have only one alien species: *Acanthocnemus nigricans* which is attracted by forest fires (Schmitz et al. 2002). The recent worldwide expansion of this species is due to the commercial export of Australian wood (Kreiss et al. 2005).

The **Mycetophagidae** (hairy fungus beetles) are a family of saproxylic insects, feeding on tree fungi. Two species, specialized on fungi growing on rotten vegetal material, are reported in the database. *Typhaea stercorea* is a well-known cryptogenic species, whereas *Litargus balteatus* is an American species found only recently in Europe

The **Ciidae** (minute tree-fungus beetles) are another family of saproxylic insects feeding on tree fungi. Only one species (out of 76 occurring in Europe) is reported here as alien, *Xylographus bostrichoides*. This small insect probably originates from Asia and has to date been found in 19 European countries.

The **Mordellidae** (tumbling flower beetles) are a large family (256 native species in Europe) of flower-dwelling insects, with endophytic larvae. Only one species, *Mordellistena cattleyana*, is considered as an alien in Europe. This is a neotropical insect whose larvae develop inside tissues of ornamental orchids (Costa Lima 1955). This behaviour may have enabled its importation through the horticultural trade, since it has been found in Germany and the Netherlands.

The **Ripiphoridae**, formerly spelled Rhipiphoridae (wedge-shaped beetles), are a small family of strange parasitic insects. Their larvae develop in other insect orders, namely Hymenoptera, Orthoptera or Dictyoptera. One species, *Ripidius pectinicornis*, has sometimes been found in harbours, along with its host cockroaches (mainly *Blatta orientalis*).

The **Zopheridae** (ironclad beetles) were previously included in the Colydiidae. This is a family of saproxylic, bark-living insects with 125 native species in Europe. The three species reported as aliens in Europe are probably predators of other saproxylic insects. They are established in one country only, or a small number of countries in the case of *Pycnomerus inexpectus*, a species found in tropical greenhouses.

The **Tenebrionidae** is mainly composed of saprophagous species. Many species are xerophiles or thermophiles, which explains their predominance in areas with hot climate and their low representation in more temperate zones (Dajoz 2002). About 15 tenebrionid alien species are present in Europe (1.1% of European tenebrionid fauna). The majority of these species are associated with spoiled or wet cereals (Weidner et al. 1984). They include very damaging pests, such as species of *Tribolium*, which enter cracks in wet or already damaged seeds, and *Alphitobius* spp., which feed on mildewed food products.

The **Salpingidae** (narrow-waisted bark beetles) are a small family of saproxylic beetles with 18 native species in Europe. One species only is mentioned here, *Aglenus brunneus*, formerly included in the Colydiidae (Zopheridae). It is a very small, blind insect, often found in stables or poultry houses, where it feeds on animal waste (Dajoz 1977).

The **Anthicidae** (antlike flower beetles) are small beetles resembling ground beetles. Four species are considered as aliens, among 310 native species living in Europe. These insects typically feed on rotten vegetal material, which has been heated through fermentation. These life history traits probably enable a wide tolerance to cold temperatures, and some species are cosmopolitan, found everywhere in the world, from tropical to boreal climates, e.g. *Omonadus floralis*, recorded in 40 countries.

8.5.3 Temporal trends

Some Coleoptera species were introduced to Europe a very long time ago. Fossils of alien species have even been found in archeological sites, such as the blind flightless beetle *Aglenus brunneus* in Iceland (Buckland et al. 2009) and *Amara aulica* (alien but native in Europe), which arrived in the Faroe islands with the Viking settlers

(Brandt 2006). But the first date of introduction of a new species into a country is often difficult to establish. A species could have been present for years without its presence being noticed immediately. Particularly relevant here are small or inconspicuous species lacking agronomic or economic impact (e.g. Ptiliidae), and members of neglected or hard to identify taxonomic groups (e.g. Cryptophagidae and Staphylinidae).

The precise date of the first record is available for 201 species (i.e. 73.1% of aliens). The first statistical data derives from the beginning of the 19th century with the introduction of the nitidulid *Carpophilus hemipterus* in 1800 by the historical opening of trade routes (Audisio 1993). Then comes the trogossitid *Tenebroides mauritanicus* in 1803, and the anobiid *Nicobium castaneum* in 1807. The endomychid *Holoparamecus depressus* arrived in 1843 and the anobiid *Lasioderma sericorne* in 1848. These detritivores are all associated with stored food products or wood.

We observed an accelerating increase in the number of new records per year (figure 8.5.2), from 0.1 p.a. between 1800–1849 to 3.5 p.a. during 2000–2007, with an intermediate level of 1.3 p.a. during the period 1900–1924. During this last period, 33 new alien species were recorded, including 14 alone for the year 1900. This unexpected increase coincides with the industrial revolution of the first developing European countries (Cosseron and Faverjon 1991) (Great Britain, Belgium, France, and Germany) and with the increase in imports ensuing from it.

8.5.4 Biogeographic patterns

8.5.4.1 Origin of alien species

Alien species come from all continents except Antarctica (figure 8.5.3) (arthropods most represented on this continent are Collembola and mites rather than beetles) (Schulte et al. 2008). The considerable periods of environmental stress in Antarctic (Benoit et al. 2009) limit the diversity of insects, even though a very few beetles do occur there (Vernon et al. 1999), such as the ground-beetles *Amblysogenium pacificum* and *A. minimum*. These factors explain easily the absence of invasives coming from Antarctic.

About 82 aliens have origins currently considered cryptogenic. These are cosmopolitan species or distributed mainly in on one or more ecozones, with a tendency to become cosmopolitan. This is particularly the case with the cryptophagid *Cryptophagus cellaris*, a holarctic species which has become practically cosmopolitan following international commercial exchanges (Delobel and Tran 1993).

Asia is the most important source of aliens, with 58 species established in Europe (21%), comprising Dermestidae (13 spp.), Staphylinidae (8 spp.), Nitidulidae (6 spp.), Anthicidae (4 spp.) and Carabidae (3 spp.). These families are generally associated with stored products, crops, decomposing matter such as compost, and to a lesser extent with wood. The 16 other families number one or two species of aliens each.

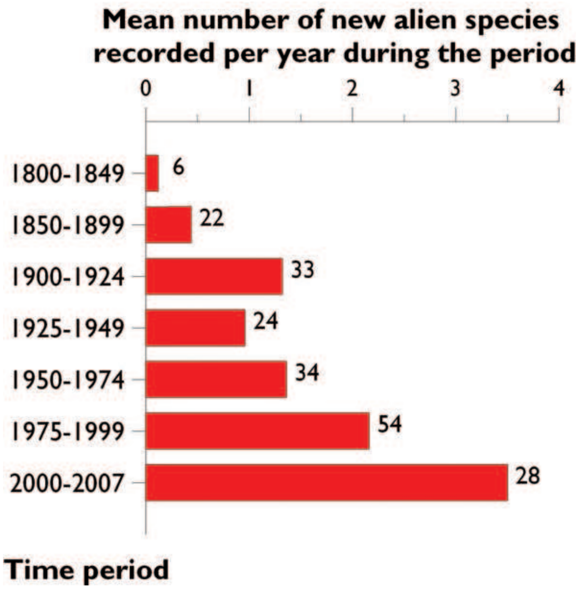

Figure 8.5.2. Temporal changes in the mean number of new records per year of alien Coleoptera species of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae, from 1800 to 2007. The number over each bar indicates the absolute number of species newly recorded per time period.

About 35 aliens come from Africa and these comprise Nitidulidae (5 spp.), Carabidae (3 spp.), Histeridae (3 spp.), Hydrophilidae (3 spp.) and Tenebrionidae (3 spp.). Nitidulidae and Tenebrionidae have been transported through stored food products. The mode of introduction is unknown for Carabidae and Hydrophilidae. There are also 14 other families having one or two alien species, which are partly associated with stored food products and wood.

The 55 aliens coming from the American continent (20% of the all alien species to Europe), include 24 species from North America and 31 species from Central and South America. From North America, the principal families are Dermestidae (7 spp.), Nitidulidae (6 spp.) and Tenebrionidae (4 spp.). Four species of Staphylinidae and four species of Ptiliidae derive from Central and South America. As for Asia and Africa, the neoarctic and neotropic aliens are mainly associated with foodstuffs and cultures. About 16 other families coming from America with one or two alien species have also been recorded in Europe.

Relatively few aliens originate from Australia. The 25 species of Australian origin include Latridiidae (4 spp.), Ptiliidae (4 spp.) and Staphylinidae (3 spp.). These species have no economic impact. The 12 other families include one or two alien species each, among which are species of the stored food products (*Ptinus ocellus*, *Anthrenus oceanicus*, *Brachypeplus mauli*) or living under the tree bark (*Ptinella cavelli* and *P. errabunda*).

The aliens with a specifically tropical origin (Pantropical) are the least presented in Europe with 20 species, that is to say 7% of all exotic species to Europe. The families

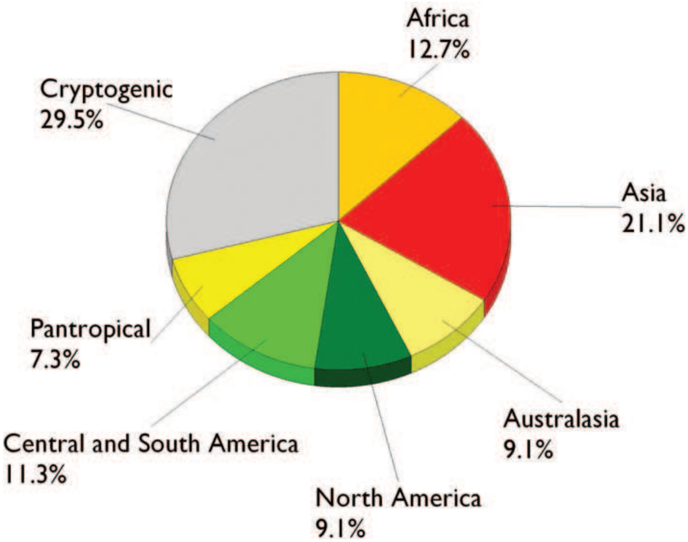

Figure 8.5.3. Origin of the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae

with the most species are Anobiidae (3 spp.), Bostrichidae (3 spp.) and Tenebrionidae (3 spp.). The eight other families have only one or two species each. These tropical aliens are associated with stored food products and fruits.

During different time slices, the origin of alien species has increasingly diversified (figure 8.5.4). The number of ecozones represented has increased from three (Africa, Asia, Pantropical) during 1800–1849 to six since 1950–1974 (Africa, Asia, Australasia, Central and South America, North America, Pantropical). The geographic source has also varied temporally although Asia has always been both an important and early region of origin. This situation can be explained by the opening of the trade route between Europe and India by the Cape of Good Hope at the end of the 15th century (which was also the sole sea route before the opening of the Suez Canal in 1869) and the strong Western influence which followed, the opium wars and the East India Companies, which revolutionized methods and the extent of the trade with Asia.

We highlight especially two ambiguous periods for biological invasions: 1850–1899 and 1925–1949. During the first period, no new record of an alien from Africa was recorded in Europe. The same goes for the second period with a fall of the number of new arrivals detected from South America (nine in 1900–1924 and only two in 1925–1949). These phenomena may coincide with the Great Depression, the result of the economic crisis of 1929 (Cosseron and Faverjon 1991, Gravereau and Trauman 2001), which affected both the level of protectionism on trade routes and the overall volume of international economic exchange between Europe and its colonies. The consequence for South America, Asia and Africa was "the crisis of dessert products", coinciding with the fall of the purchasing power in Europe and North America. Thus in Brazil for example, in an attempt to control the market, coffee was burned in engines (Launay 1999).

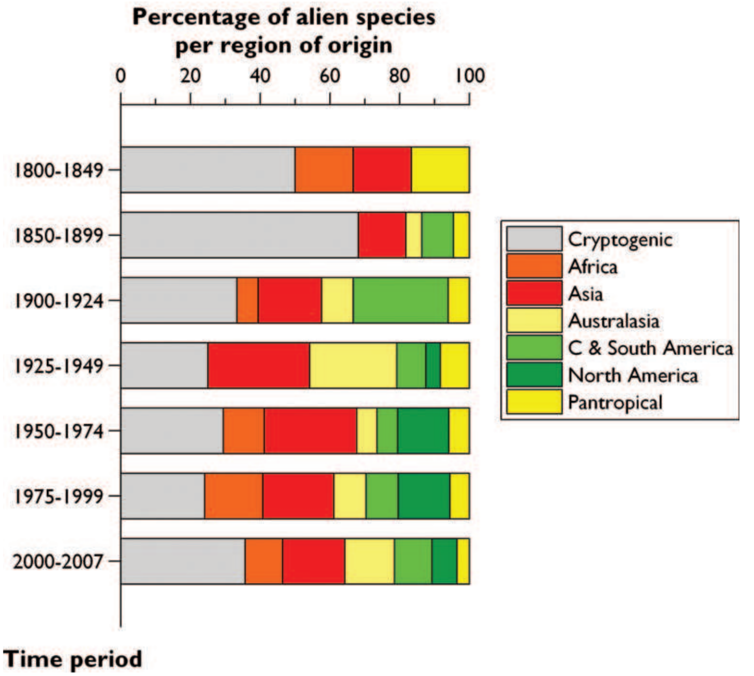

Figure 8.5.4. Temporal changes in the origin of the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae

The late arrival of aliens to Europe from North America is remarkable (first record in 1935) and probably corresponds to weak exports of foodstuffs towards Europe (except cereals). For forest biotopes especially, the North American component of species is small and of limited economic impact in Europe (Dajoz 2007).

8.5.4.2 Distribution of alien species within Europe and their range expansion

The majority of European countries have been directly affected by alien species (figure 8.5.5), but there is a very great mismatch in the number of species present in one country versus another.

The archipelago of Svalbard, with an insect fauna of a meagre 230 species (Coulson 2007), seems free from aliens. As in the case of Antarctica, the strong environmental contraints (harsh temperatures, shortened seasons and strong winds) have evidently limited the colonization of insects (Hulle et al. 2008) and geographical isolation has posed a barrier. For Macedonia there is a lack of readily accessible data (Tomov 2009), which has prevented us updating the situation there.

The countries/islands most affected by aliens are France (126), Germany (107), Italy (101), Austria (98), Great Britain (97), Switzerland (91), the archipelago of Azores (92), Denmark (89) and the Czech Republic (84).

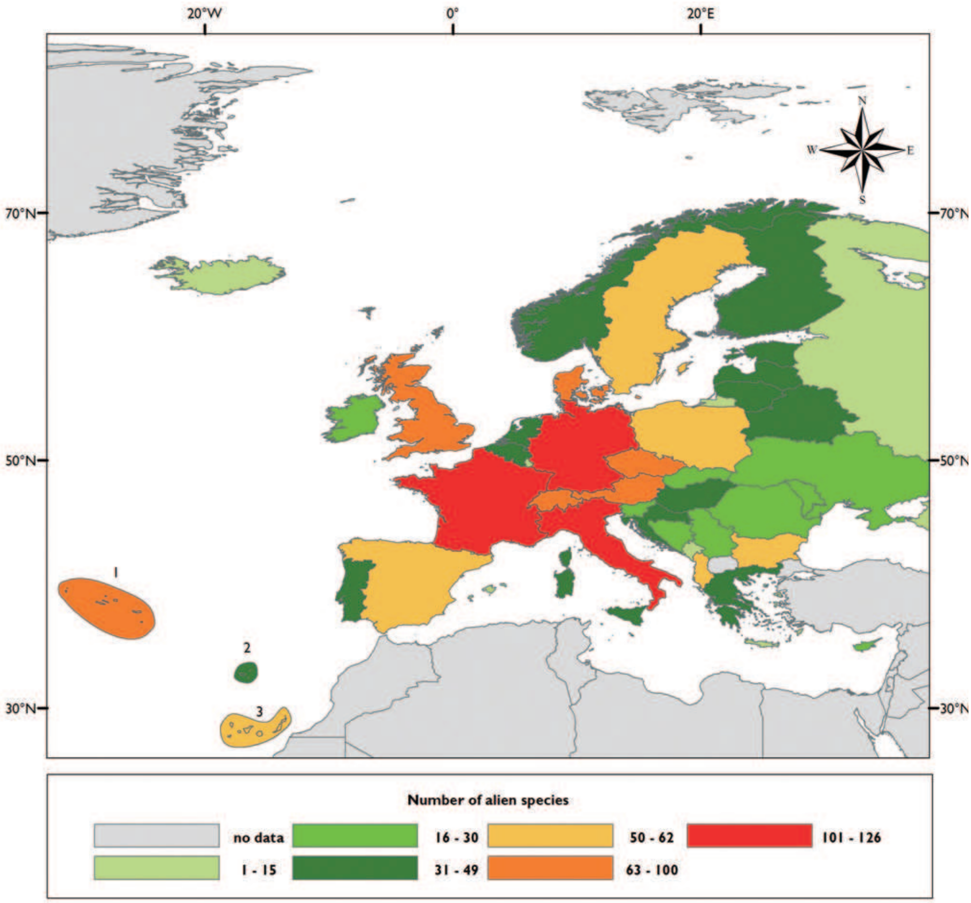

Figure 8.5.5. Comparative colonization of continental European countries and islands by by the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

The number of aliens per country is not significantly correlated with Global Domestic Product per capita (International Monetary Fund), latitude, nor longitude of the centroid of the country. In contrast, the number of aliens per country is significantly correlated with import (Spearman-Rho 0.650, P-value < 0.001) from 2003 to 2008 (The World Factbook) and also more weakly with area (Spearman-Rho 0.432, P-value < 0.01).

In spite of its geographical isolation (1500km from Europe, 1450km from Africa and 3900km from North America) and its small area, the archipelago of Azores has a large number of aliens. Since their historical discovery, the geographic position of the Azores has made the islands a strategic harbour for transatlantic ships, resulting in the introduction overall of several hundreds of taxa (Haggar 1988, Heleno 2008). Twenty-four alien species have been recorded exclusively in the Azores archipelago.

Indeed, alien native species in Europe have colonized islands more than other continental countries. The archipelago of Azores is the most affected with 126 alien species to Europe, followed by Great Britain (with 58 aliens), Faroe Islands (32 aliens) and Canary Islands (32 aliens). Perhaps surprisingly, Austria is the most important continental country affect by alien native to Europe, with 13 species.

8.5.5 Main pathways to Europe

The most important pathways for accidental invasions of exotic species to Europe are those closely bound to international transport, whereas the most important processes relating to deliberate introductions are the biological control of agricultural pests and the pollination of crops (Ruiz and Carlton 2003). Rapidly developing international trade and the reduction of travel times by air to less than two days, have meant that a living insect can be transported almost any part of the world (Mouchet et al. 1995).

Only three species have been introduced intentionally in Europe, two for biological control. The first is the cybocephalid beetle *Cybocephalus nipponicus*, originating in South Korea (Evans et al. 2005) and introduced into Italy for the control of cochineals bugs (Diaspididae) (Lupi 2002). The second species is *Ripidius pectinicornis* (Ripiphoridae), a parasitoid of the german cockroach *Blattella germanica* (Falin 2001) which was released from culture and is now present in several European countries (Bétis 1912). The third species is the tenebrionid *Zophobas morio* which has been used for bird and especially lizard food (Thomas 1995).

About 98.9% of aliens have been introduced accidently in Europe. The exact pathway of introduction is difficult to establish. The introduction vector is unknown for 123 aliens out of the total of 275. Theses aliens are essentially detritiphagous, saproxylophagous or predatory species.

The first clearly identified means of importation is via stored products and crops (approximately 120 aliens, or 40%). This can be explained by the importance of the international stored products trade (cereals, fruits and vegetables) and the primary position of Coleoptera as pests of stored products (Delobel and Tran 1993). About 20 Coleoptera have been implicated directly in the transport of woods. Some species have been found in wood derivatives such as *Dinoderus minutus*, a bostrichid introduced with furniture and bamboo-work (Lesne 1901). Few species have been identified as transported with horticultural or ornamental products, despite the increase of economic importance of ornamental pot plants (Lawson 1996), in sharp contrast for example to the situation in Lepidoptera (see Chapter 11). However, the level may be underestimated for this route, as some Coleoptera tend to occur in compost and may pass unnoticed via the pot plant trade.

The extruded starch products used as impact protection for fragile packing can even be a food source for stored grains pests (Fraga et al. 2009) as for *Cryptolestes ferrugineus*, *Lasioderma serricorne* and *Tribolium castaneum*. Thus starch-packings could become a new vector of introductions in the future.

8.5.6 Most invaded ecosystems and habitats

The anthropogenic habitats most strongly colonized by coleopteran alien species (figure 8.5.6), are buildings (50%), cultivated lands (20%) and forest habitats (10%). The large proportion of species associated with foodstuffs explains this relation. Conversely, the weak colonization of pseudo-natural habitats can be explained by the near-absence of phytophagous, and more particularly phyllophagous species among the coleopteran families treated here. This result contrasts with the situation for other groups of predominantly phytophagous insects (Cerambycidae, Chrysomelidae, Lepidoptera: Chapter 8.1, 8.3, 11).

In spite of the popularity of exotic species for the aquatic animal and plant trade (Leppäkoski et al. 2002) and the fact that migrating waterfowl can transport aquatic invertebrates or their eggs (Figuerola et al. 2003), surprisingly no water beetle has been introduced into Europe, except for the dytiscid *Megadytes costalis* (again contrasting with the situation for Lepidoptera, the aquatic Pyraloidea: Chapter 11). This low importance of the aquatic route in Coleoptera is also observed in the United States, where only 2.2% of the invasive arthropods are aquatics (Pimentel et al. 2005).

8.5.7 Ecological and economics impacts

Most alien species do not become invasive in their new locations (Genovesi and Shine 2003). It is often difficult to predict whether a new introduction will actually become established (Streito and Martinez 2008). However, the subset of alien species that are invasive may have significant environmental, economic and public health impacts and threaten the wholesale homogenisation of ecosystems (Sefrova 2005).

Invasive alien species are now considered to be the second greatest cause of global biodiversity loss after direct habitat destruction (Simberloff 2001) and have adverse environmental, economic and social impacts from the local level upwards.

The invasion of most Coleoptera treated here bears a direct relation to human presence (synanthropic species). Their impact is essentially with stored foodstuffs which they can extensively damage (Sefrova 2005). Coleoptera damaging stored food products on a global economic scale are very few (Delobel and Tran 1993), but include several species of aliens in Europe, among which are *Cryptolestes ferrugineus*, *C. pusillus*, *Lasioderma serricorne*, *Oryzaephilus surinamensis*, *Rhyzopertha dominica*, *Tribolium castaneum*, *T. confusum* and *Trogoderma granarium*. The impact of insect pests in a given situation can widely fluctuate depending on various parameters, in particular on production levels and the commercial value of those products infested both in time and in a geo-economic context. However, these synanthropic species are not known to have a direct effect on biodiversity.

The situation for agronomic and forest species can be different. The buprestid *Agrilus planipennis,* recently recorded in European Russia, is a very good example. This xylophagous East Asian species is presently causing significant damage to ash trees (*Fraxinus* spp.) in North America (Baranchikov et al. 2008). *A. planipennis* has killed

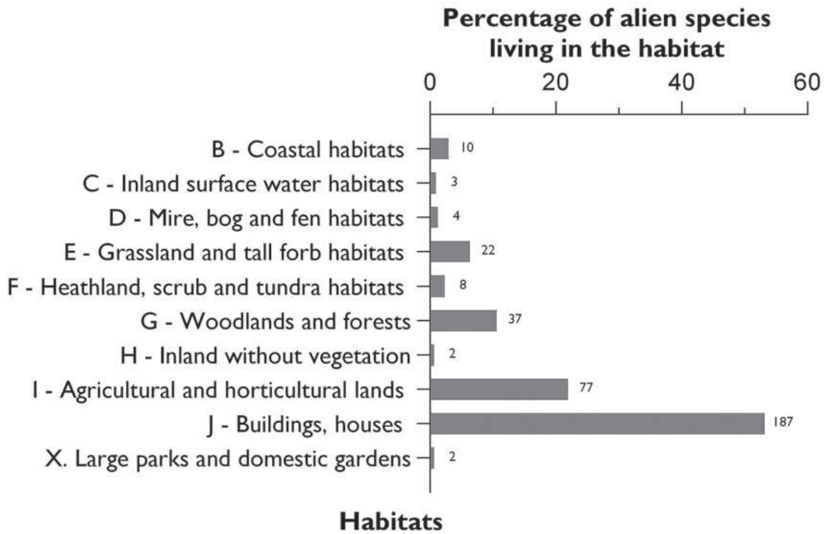

Figure 8.5.6. Main European habitats colonized by the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. The number over each bar indicates the absolute number of alien coleopterans recorded per habitat. Note that a species may have colonized several habitats.

over 15 million forest and ornamental trees in several US States in less than 10 years (Poland and McCullough 2006). It is alarming that European ash trees are not more resistant than those of North America (Baranchikov et al. 2008). *Agrilus planipennis* could become a serious pest in Europe with a dramatic economy impact as well as potentially for biodiversity associated with *Fraxinus*.

Many species are associated with compost and even while their economical impact may be negligible (as mainly predators or detritivores), ecological disruption may still occur. This appears to be the case with the Staphylinid *Lithocharis ochracea*. This native beetle has declined, supplanted by the alien species *L. nigriceps* (Ødegaard and Tømmerås 2000, Tronquet 2006).

Even if the eradication of invasive species seems possible in Europe and in particular for mammals (Genovesi 2005), the possibility of eradication of invasive Coleoptera appears much more remote.

8.5.8 Conclusion

On of the most striking consequences of globalization is the increase in the problem of invasive species (Perrings et al. 2005). The volume of international trade and travel is now so great, and the modes of entry so varied, that not all consignments or routes of entry can be screened (Levine and D'Antonio 2003). Three categories are particularly important to highlight for the coleopteran alien species treated here: synantropic

Figure 8.5.7. Habitus of some Coleoptera species alien *to* Europe. **a** *Ernobius mollis* **b** *Tribolium castaneum* **c** *Oryzaephilus surinamensis* **d** *Alphitobius diaperinus* **e** *Cryptolestes duplicatus* **f** *Dermestes lardarius* **g** *Gnathocerus cornutus* **h** *Rhizopertha dominica* **i** *Necrobia ruficollis* **j** *Trechicus nigriceps* **k** *Lyctus brunneus* **l** *Gibbium psylloides* (Credit: Pierre Zagatti).

habitats with essentially stored products, compost (probably that associated with ornamental plants), and forest or wood-derived products.

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References

Aberlenc HP, Allemand R (1997) Acclimation en France de *Ptilodactyla exotica*, espèces à moeurs anthropophiles (Coleoptera, Ptilodactylidae). *Bulletin de la Société entomologique de France* 102: 93–102.

Abood F, Murphy RJ (2006) World distribution of *Minthea rugicollis* (Coleoptera: Lyctidae). *Journal of Tropical Forest Science* 18 (4): 250–254.

Allemand R (2008) Anobiidae nouveaux ou méconnus de la faune de France (3e note) (Coleoptera). *Bulletin de la Société entomologique de France* 113 (3): 397–402.

Alonso-Zarazaga MA, Sánchez-Ruiz M, and Sánchez-Ruiz A (2003) Une nueva familia de Coleoptera para Espana: Acanthocnemidae. *Bol. S.E.A.* 32: 179–180.

Anderson R (1997) Northern Ireland species inventories. Rove beetles (Coleoptera: Staphylinidae). Environment and Heritage Service. http://www.ehsni.gov.uk/pubs/publications/Staph.pdf

Anderson R, McFerran D, Cameron A (2000) The Ground Beetles of Northern Ireland (Coleoptera, Carabidae). Atlas of the northern Ireland Flora and Fauna, Volume 1. Ulster Museum, U.K., Belfast. 256 pp.

Angus RB, Wilson CJ, Maté JF, Hammond PM, Mann DJ (2003) *Saprosites mendax* (Blackburn) and *S. natalensis* (Peringuey) (Scarabaeoidea, Aphodiidae), two species introduced into Britain. *Proceedings of the Second Pan-European Conference on Saproxylic Beetles*, 2003, 72–76.

Arndt E (2006) Niche occupation by invasive ground-dwelling predator species in Canarian laurel forests. *Biological Invasions* 8: 893–902.

Audisio P (1993) Coleoptera Nitidulidae - Kateretidae. Fauna d'Italia, vol. 32. Calderini, Italia, Bologna. 971 pp.

Baranchikov Y, Mozolevskaya E, Yurchenko G, Kenis M (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. *OEPP/EPPO Bulletin* 38: 233–238.

Baraud J (1985) Coléoptères Scarabaeoidea: faune du Nord de l'Afrique, du Maroc au Sinaï. Lechevalier, France, Paris. 651 pp.

Baraud J (1992) Faune de France: France et régions limitrophes . 78 . Coléoptères Scarabaeoidea d'Europe. Fédération française des sociétés de sciences naturelles and Société linnéenne de Lyon, France, Lyon. 856 pp.

Barsevskis A, Bicevskis M, Valainis U, Savenkovs N, Cibulskis R, Kalnins M, Strode N (2004) Faunistic records of the beetles (Hexapoda: Coleoptera) in Latvia. 1. *Acta Biol. Univ. Daugavp.* 4 (2): 93–106.

Batten R (1976) De Nederlandse soorten van de keverfamilie Mordellidae. *Zoologische Bijdragen* 19: 3–37.

Beal RS, Kadej M (2008) Description of the Larva of *Sefrania Bleusei* Pic and assignment of *Sefrania Sabulorum* (Beal) to the New Genus *Araphonotos* Beal and Kadej (Coleoptera: Dermestidae). *Entomological News* 119: 245–250.

Bellés X (1985) Habitats and food habits of the Gibbiinae (Coleoptera: Ptinidae). *Bull. Inst. Cat. Hist. Nat.* 50: 263–267.

Bellés X, Halstead DGH (1985) Identification and geographical distribution of *Gibbium aequinoctiale* Boieldieu and *Gibbium psylloides* (Czenpinski) (Coleoptera: Ptinidae). *Journal of Stored Products Research* 21: 151–155.

Bengtson SA (1981) Terrestrial invertebrates of the Faroa Islands: III. Beeltes (Coleoptera): check-list, distribution, and habitats. *Fauna norv. Ser. B.* 28: 52–82.

Benoit JB, Elnitsky MA, Schulte GG, Lee RE, Denlinger DL (2009) Antarctic collembolans use chemical signals to promote aggregation and egg laying. *Journal of Insect Behavior* 22: 121–133.

Bercedo P (1997) El género *Omorgus* Erichson, 1847 en la Peninsula Ibérica (Coleoptera, Scarabaeoidea: Trogidae). *Bol. S.E.A.* 17: 29–31.

Bercedo P, Arnaiz L, Coello P, Baena M (2005) *Ozognathus cornutus* (LeConte, 1859) new anobiid for the Iberian fauna (Coleoptera: Anobiidae). *Boletin Sociedad Entomologica Aragonesa* 37: 213–214.

Bercedo P, Becerra RG, Arnaiz L (2008) El género *Calymmaderus* Solier, 1849 nuevo para Canarias y descripcion de una nueva especie (Coleoptera: Ptinidae: Dorcatominae). *Boletin Sociedad Entomologica Aragonesa* 42: 33–35.

Bétis L (1912) Faune entomologique Armoricaine, Coléoptères Rhipiphoridés. Imprimerie Oberthur, France, Rennes. 40 pp.

Borges PAV (1990) A checklist of the Coleoptera from the Azores with some systematic and biogeographic comments. *Bol. Mus. Mun. Funchal* 42 (220): 87–136.

Borges PAV, Vieira V, Dinis F, Jarroca S (2005) List of Arthropods (Arthropoda). *In* Borges et al. (eds.): *A list of the terrestrial fauna (Mollusc and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Angra do Heroísmo Horta, Ponta Delgada, 163–221.

Bouget C, Moncoutier B (2003) Contribution à la connaissance des Rhizophaginae de France (Coleoptera, Cucujoidea, Monotomidae). *Bulletin de la Société entomologique de France* 108 (3): 287–306.

Bouget C, Vincent R (2008) Les Latridiidae de la faune de France continentale et de Corse: mise à jour de la clé des genres et du catalogue des espèces (Coleoptera, Cucujoidea). *Bulletin de la Société entomologique de France* 113: 101–120.

Boukal DS, Boukal M, Fikacek M, Hajek J, Klecka J, Skalicky S, Stastny J, Trávnicek D (2007) Catalogue of water beetles of the Czech Republic (Coleoptera: Sphaeriusidae, Gyrinidae, Haliplidae, Noteridae, Hygrobiidae, Dytiscidae, Helophoridae, Georissidae, Hydrochidae, Spercheidae, Hydrophilidae, Hydraenidae, Scirtidae, Elmidae, Dryopidae, Limnichidae, Heteroceridae, Psephenidae). *Klapalekiana* 43 (Suppl.): 1–289.

Bowestead S (1999) A revision of the Corylophidae (Coleoptera) of the west Palaearctic region. Muséum d'histoire naturelle Genève, Suisse, Genève. 203 pp.

Brandt D (2006) More stamps and Story of the Faroe Islands. Postverk Føroya (The Faroese Postal Administration). Postverk Føroya (The Faroese Postal Administration), Denmark, Tórshavn. 360 pp.

Buckland PC, Panagiotakopulu E, and Sveinbjarnardottir G (2009) A failed invader in the North Atlantic, the case of *Aglenus brunneus* Gyll. (Col., Colydiidae), a blind flightless beetle from Iceland. *Biological Invasions* 11: 1239–1245.

Bunalski M (1999) Die Blatthornkäfer Mitteleuropas (Coleoptera: Scarabaeoidea): Bestimmung, Verbreitung, Ökologie. František Slamka, Slovakia, Bratislava. 80 pp.

Callot H (2003) *Cryptophilus obliteratus* Reitter, 1878, espèce nouvelle pour la faune de France (Coleoptera, Languriidae). *Bulletin de la Société entomologique de Mulhouse* 59 (1): 5–6.

Callot HJ (1993) Sur quelques staphylins capturés dans la Bas-Rhin et peut-être nouveaux pour la Faune de France: *Philonthus spinipes* Sharp., *Philonthus scribae* Fauvel, *Ontholestes haroldi* Eppelsheim, *Aleochara irmgardis* Vogt. *Bul. Soc. ent. Mulhouse* Janvier-Mars: 13–15.

Camerini G (2009) Factors affecting *Lymantria dispar* mortality in a willow wood in northern Italy. *Bulletin of Insectology* 62 (1): 21–25.

Cho YB (2008) Korean species of the genus *Bisnius* Stephens (Coleoptera: Staphylinidae). *Entomological Research* 38: 90–92.

Cobos A (1986) Fauna ibérica de Coleópteros Buprestidae. Consejo Superior de Investigaciones Científicas, Spain, Madrid. 364 pp.

Coiffait H (1972) Coléoptères Staphylinidae de la région paléarctique occidentale 1. Généralités, sous-famille Xantholinae - Leptotyphinae. *Supplément à la Nouvelle Revue d'Entomologie* 4: 1–593.

Cosseron S, Faverjon P (1991) L'Europe de 1815 à nos jours. Une histoire et une chronologie commentée. La Manufacture, France, Besançon. 641 pp.

Costa Lima AM (1955) Insetos do Brasil. 9° Tomo, Capitulo XXIX: Coleopteros, 3a Parte. *Escola Nacional de Agronomia, Rio de Janeiro* 11 (9): 1–289.

Coulson SJ (2007) Terrestrial and freshwater invertebrate fauna of the High Arctic archipelago of Svalbard. *Zootaxa* 1448: 41–68.

Cuppen J (2003) *Carpelimus zealandicus*, een nieuwe kortschildkever voor Nederland (Coleoptera: Staphylinidae). *Nederlandse Faunistische Mededelingen* 19: 35–40.

Curtis J (1836) British entomology; being illustrations and descriptions of the Genera of Insects found in Great Britain and Ireland. Vol XIII. pl. 578–625. Printed by Richard Taylor.

DAISIE: European Invasive Alien Species Gateway. http://www.europe-aliens.org.

Dajoz R (1977) Coléoptères Colydiidae et Anommatidae paléarctiques. Faune de France et du Bassin méditerranéen. Masson, France, Paris. 280 pp.

Dajoz R (2002) Les coléoptères carabidés et ténébrionidés: écologie et biologie. Tec et Doc, France, Paris. 522 pp.

Dajoz R (2007) Les insectes et la forêt. Rôle et diversité des insectes dans le milieu forestier. 2e édition. Tec & Doc, France, Paris. 648 pp.

Darlington PJ (1964) Australian carabid bettles XIV. Perigona. *Psyche* 71: 125–129.

De Laclos E, and Büche B (2009) La Vrillette sans peine: quatrième note (Coleoptera Anobiidae). *L'Entomologiste* 65 (4): 207–213.

Degiovanni A, Pezzi G (2007) *Anthicus catalanus* Bonadona, 1953 nuovo per l'Italia reperti di altre specie (Insecta Coleoptera Anthicidae). *Quaderno di Studi e Notizie di Storia Natuale della Romagna* 24: 69–77.

Delobel A, Tran M (1993) Les Coléoptères des denrées entreposées dans les régions chaudes. CTA/ORSTOM, France, Paris. 424 pp.

Denux O, Augustin S, Berthelot A (2007) Biodiversité des Carabidae dans les peupleraies picardes (Coleoptera). *L'Entomologiste* 63: 243–256.

Du Chatenet G (2000) Coléoptères Phytophages d'Europe. Tome 1. NAP, France, Vitry-sur-Seine. 360 pp.

Duff AG (2008) Checklist of beetles of the British Isles. A.G. Duff, United Kingdom, Somerset, Wells. 164 pp.

Enckell PH, Bengtson SA, Wiman B (1987) Serf and Waif Colonization - Distribution and Dispersal of Invertebrate Species in Faroe-Island Settlement Areas. *Journal of Biogeography* 14 (1): 89–104.

Espanol F (1979) Géneros de Dorcatominae de la fauna europea (Col. Anobiidae). Nota 92. *Misc. Zool. Barcelona* 5: 33–42.

Espanol F (1992) Coleoptera, Anobiidae. Fauna Iberica. Vol. 2. Museo Nacional de Ciencias Naturales, CSIC, Spain, Madrid. 195 pp.

Evans GA, Dessart P, Glenn H (2005) Two new species of *Aphanogmus* (Hymenoptera: Ceraphronidae) of economic importance reared from *Cybocephalus nipponicus* (Coleoptera: Cybocephalidae). *Zootaxa* 1018: 47–54.

Falcoz L (1929) Tableaux analytiques des Coléoptères de la faune franco-rhénane (France, Hollande, Belgique, Région rhénane, Valais). Vol. III: Famille 33: Cryptophagidae. Imprimerie des Miscellanea entomologica, France, Narbonne.197 pp.

Falin ZH (2001) Notes on the Occurrence of *Ripidius pectinicornis* Thunberg (Coleoptera: Rhipiphoridae) in the Continental United States and Hawaii. *The Coleopterists Bulletin* 55: 194–197.

Fauna Europaea Web Service: Fauna Europaea version 1.1. http://www.faunaeur.org.

Ferrer J (2004) Espèces de *Cynaeus* Leconte 1851, introduites en Europe du Nord. (Coleoptera, Tenebrionidae, Ulomini). *Nouvelle Revue d'Entomologie (N.S.)* 21 (2): 103–104.

Ferrer J, Andersson B (2002) Species of *Cynaeus* found in Sweden and Finland, with a note of the identity between *Cynaeus depresus* (Horn 1870) and *Cynaeus opacus* (Champion 1886) syn. conf. (Coleoptera, Tenebrionidae, Diaperini). *Entomofauna, Zeitschrift für Entomologie* 23 (12): 145–148.

Ferrer J, Martinez Fernandez JC (2008) *Blaps mortisaga* (L.) o la leyenda de la muerte, una especie introducida en Europa boreal y occidental (Coleoptera, Tenebrionidae). *Boln. Asoc. esp. Ent.* 32 (3–4): 245–261.

Figuerola J, Green AJ, Santamaria L (2003) Passive internal transport of aquatic organisms by waterfowl in Donana, south-west Spain. *Global Ecology and Biogeography* 12: 427–436.

Fikacek M, Boukal M (2004) *Pachysternum capense*, a new genus and species for Europe, and updated key to genera and subgenera of European Sphaeridiinae (Coleoptera: Hydrophilidae). *Klapalekiana* 40: 1–12.

Fraga FB, Alencar IDCC, Tavares MT (2009) Insect pests dissemination by extruded starch packages. *Neotropical Entomology* 38: 548–549.

Franz JM (1958) Studies on *Laricobius erichsonii* Rosenh (Coleoptera: Derodontidae), a predator on Chermesids. Part 1, Distribution, life-history and ecology. *Entomophaga* 3 (2): 109–164.

Freude H, Harde KW, Lohse GA (1964) Die Käfer Mitteleuropas, Band 4: Staphylinidae I (Micropeplinae bis Tachyporinae). Goecke & Evers, Germany, Krefeld. 264 pp.

Freude H, Harde KW, Lohse GA (1967) Die Käfer Mitteleuropas, Band 7: Clavicornia. Goecke & Evers, Germany, Krefeld. 310 pp.

Freude H, Harde KW, Lohse GA (1969) Die Käfer Mitteleuropas, Band 8: Teredilia, Heteromera, Lamellicornia. Goecke & Evers, Germany, Krefeld. 388 pp.

Freude H, Harde KW, Lohse GA (1971) Die Käfer Mitteleuropas, Band 3: Adephaga 2, Palpicornia, Histeroidea, Staphylinoidea 1. Goecke & Evers, Germany, Krefeld. 365 pp.

Freude H, Harde KW, Lohse GA (1974) Die Käfer Mitteleuropas, Band 5: Staphylinidae 2 (Hypocyphtinae und Aleocharinae), Pselaphidae. Goecke & Evers, Germany, Krefeld. 381 pp.

Freude H, Harde KW, Lohse GA (1979) Die Käfer Mitteleuropas, Band 6: Diversicornia. Goecke & Evers, Germany, Krefeld. 367 pp.

Freude H, Harde KW, Lohse GA (1989) Die Käfer Mitteleuropas: 1. Supplementband mit Katalogteil. Bd. 12, 346 S. Goecke & Evers, Germany, Krefeld. 245 pp.

Gamarra P, Outerelo R (2005) Catalogo Iberobalear de los Aleocharinae (Coleoptera: Staphylinidae). *Boletin Sociedad Entomologica Aragonesa* 37: 1–81.

Gamarra P, Outerelo R (2009) Catalogo Iberobalear de los Micropeplinae y Proteininae (Coleoptera: Staphylinidae). *Boletin Sociedad Entomologica Aragonesa* 45: 207–211.

Genovesi P (2005) Eradications of invasive alien species in Europe: a review. *Biological Invasions* 7: 127–133.

Genovesi P, Shine C (2003) European Strategy on Invasive Alien Species. Council of Europe, Strasbourg, t-pvs (2003) 7 rev. 50 pp.

Glavendekic M, Mihajlovic L, Petanovic R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro. *Plant protection and plant health in Europe: introduction and spread of invasive species*, held at Humboldt University, Germany, Berlin, 9–11 June 2005, 229–230.

Gomy Y (2006) Contribution à l'établissement des catalogues régionaux: Histeroidea (Coleoptera). V. *L'Entomologiste* 62 (3–4): 101–115.

Gomy Y (2008) Contribution à l'établissement des catalogues régionaux: Coleoptera Histeridae VII. *L'Entomologiste* 64 (6): 325–347.

Gomy Y (2009) Contribution à l'établissement des catalogues régionaux: Coleoptera Histeridae VII. *L'Entomologiste* 65 (6): 313–328.

Gravereau J, Trauman J (2001) Crises financières. Economica, France, Paris. 459 pp.

Haggar JP (1988) The structure, composition and status of the cloud forests of Pico Island in the Azores. *Biological Conservation* 46: 7–22.

Haines CP, Rees DP (1989) Guide pratique des types d'insectes et d'acariens qui s'attaquent au poisson traité. FAO Document technique sur les pêches - 303. Organisation des Nations Unies pour l'alimentation et l'agriculture, Italia, Rome. 33 pp.

Halperin J, Geis KU (1999) Lyctidae (Coleoptera) of Israel, their damage and its prevention. *Phytoparasitica* 27 (4) 257–262.

Hava J (2003) World catalogue of the Dermestidae (Coleoptera). Studie a zprávy Okresního muzea Praha-východ, Supplementum 1, Czech Republic, Praha. 196 pp.

Hava J: A Catalogue of World Dermestidae. http://www.dermestidae.wz.cz.

Heleno RH (2008) The impact of alien plants on native biota in the Azores: a food web approach. *PhD thesis. School of Biological Sciences, University of Bristol, England*. 179 pp.

Hemp C, Dettner K (2003) Description of larvae of the genus *Formicomus* laferte, and data on the life cycles of *Omonadus floralis* (Linne) and *Notoxus monoceros* (Linne) (Coleoptera: Anthicidae). *Coleopterists Bulletin* 57: 361–368.

Hermann A, Baena M (2004) New records of Dermestidae (Coleoptera) for Spain and Europe. *Boln. S.E.A.* 34 (2004): 211–213.

Holland JM (2002) The agroecology of carabid beetles. Intercept Limited, UK, Andover. 356 pp.

Hulle M, Bonhomme J, Maurice D, and Simon JC (2008) Is the life cycle of high arctic aphids adapted to climate change? *Polar Biology* 31: 1037–1042.

Hurka K (1996) Carabidae of the Czech and Slovak Republics. Kabourek, Czech Republic, Zlin. 565 pp.

Iablokoff-Khnzorian SM (1975) Etude sur les Erotylidae (Coleoptera) palearctiques. *Acta Zoologica Cracoviensia* 20 (8).

Imperial Institute of Entomology (1930) The Review of applied entomology. Series A, Agricultural. The Imperial Institute of Entomology, England, London. 895 pp.

International Monetary Fund: World Economic Outlook database. http://www.imf.org/external/pubs/ft/weo/2009/02/weodata/index.aspx [accessed October 2009].

Jeannel R (1942) Coléoptères Carabiques, II. Collection Faune de France. Lechevalier, France, Paris. 600 pp.

Kadej M (2005) Data on the occurence of some species of Dermestidae (Coleoptera) in Poland. *Wiadomosci Entomologiczne* 24 (1): 21–31.

Kirejtshuk AG, James DG, Heffer R (1997) Description and biology of a new species of *Cybocephalus* Erichson (Coleoptera: Nitidulidae), a predator of Australian citrus whitefly. *Australian Journal of Entomology* 36: 81–86.

Korge H (2005) Rote Liste und Gesamtartenliste der Kurzflügelkäfer (Coleoptera: Staphylinidae) von Berlin. In Der Landerbeauftragte für Naturschutz und Landschaftspflege / Senatsverwaltung für Stadtentwicklung (Hrsg.): Rote Listen der gefährdeten Pflanzen und Tiere von Berlin. CD-ROM.

Kreiss E-J, Schmitz A, and Schmitz H (2005) Morphology of the prothoracic discs and associated sensilla of *Acanthocnemus nigricans* (Coleoptera, Acanthocnemidae). *Arthropod Structure & Development* 34: 419–428.

Kuschel G (1990) Beetles in a suburban environment: a New Zealand case study. The identity and status of Coleoptera in the natural and modified habitats of Lynfield, Auckland (1974–1989). DSIO Plant Protection Report no. 3. New Zealand Department of Scientific and Industrial Research, New Zealand, Auckland. 118 pp.

Laibner S (2000) Elateridae of the Czech and Slovak Republics. Kabourek, Czech Republic, Zlin. 292 pp.

Launay M (1999) Versailles, une paix baclée ? Le XXème siècle est mal parti. Complexe, France, Paris. 188 pp.

Lawson RH (1996) Economic importance and trends in ornamental horticulture. *Ninth international symposium on virus diseases of ornamental plants*, Israel, Herzliya, 17–22 March, 1996. 226–237.

Leppäkoski E, Gollasch S, and Olenin S (2002) Invasive Aquatic Species of Europe Distribution, Impacts and Management. Kluwer Academic, Nederland, Dordrecht. 583 pp.

Leseigneur L (1972) Coléoptères Elateridae de la faune de France continentale et de Corse. *Bulletin mensuel de la Société linnéenne de Lyon*, vol. 41, suppl. 1–380.

Lesne P (1901) Synopsis des Bostrychides paléarctiques. *L'Abeille* 30: 73–136.

Lesne P (1904) Supplément au Synopsis des Bostrychidae paléarctiques. *L'Abeille* 30: 153–168.

Levine JM, and D'Antonio CM (2003) Forecasting biological invasions with increasing international trade. *Conservation Biology* 17: 322–326.

Libungan L, Gíslason GM, and Þórðarson T (2008) Varmasmiður – stærsta bjalla á Íslandi (English summary: The ground beetle Carabus nemoralis – biggest beetle in Iceland). *Náttúrufræðingurinn* 77: 15–18.

Lima AMdC (1955) Insetos do Brasil. 9° Tomo, Capitulo XXIX. Coleopteros, 3a Parte. Escola Nacional de Agronomia, Série didatica, Brazil, Rio de Janeiro. 289 pp.

Luff M (1998) Provisional atlas of the ground beetles (Coleoptera, Carabidae) of Britain. Biological Records Centre, England, Huntingdon. 194 pp.

Luff ML (2007) The Carabidae (ground beetles) of Britain and Ireland (Second Edition). Handbooks for the identification of British Insects. Vol 4 Part 2. Royal Entomological Society, England, Shrewsbury. 247 pp.

Luka H, Nagel P, Feldmann B, Luka A, Gonseth Y (2009) Checkliste der Kurzflügelkäfer der Schweiz (Coleoptera: Staphylinidae ohne Pselaphinae). *Mitteilungen der Schweizerischen Entomogischen Gesellschaft* 82: 61–100.

Lupi D (2002) *Cybocephalus nipponicus* Endrody-Younga (Coleoptera Cybocephalidae) on *Diaspis echinocacti* (Bouche) in Liguria. *Bollettino di Zoologia Agraria e di Bachicoltura* 34: 463–466.

Machado A (1976) Introduction to a faunal study of the Canary Islands' Laurisilva, with special reference to the ground-beetles (Coleoptera, Caraboidea). In: Kunkel G (Ed) *Biogeography and Ecology in the Canary Islands*. The Hague, Junk, Netherlands. 347–411.

Machado A, Oromi P (2000) Elenco de los Coleopteros de las islas Canarias. Catalogue of the Coleoptera of the Canary islands. Instituto de Estudios Canarios, Spain, Tenerife, La Laguna. 306 pp.

Maddison DR, Schulz KS, Maddison WP (2007) The Tree of Life Web Project. *Zootaxa* 1668: 19–40.

Mann DJ (2006) *Ptilodactyla exotica* Chapin, 1927 (Coleoptera: Ptilodactylidae: Ptilodactylinae) established breeding under glass in Britain, with a brief discussion on the family Ptilodactylidae. *Entomologist's Monthly Magazine* 142: 67–79.

Mannerkoski I, Ferrer J (1992) *Cynaeus opacus* Champion, a new tenebrionid beetle in Finland (Coleoptera, Tenebrionidae). *Entomologica Fennica* 31 (8): 95–97.

Martinez M, Cocquempot C (1985) Sur la présence en France de *Reesa vespulae*, espèce indésirable (Coleoptera Dermestidae). *L'Entomologiste* 41 (1): 21–25.

Mazur S (1989) Note synonymique sur les genres *Pactolinus* MOTSCHULSKY, *Pachylister* LEWIS et *Macrolister* LEWIS (Col. Histeridae). *Nouv. Revue Ent. (N.S.)* 6 (1): 84.

Mendonça E, and Borges PAV (2009) Distribution of the Exotic Arthropods from the Azores. Portugal, Univ. Azores, Angra do Heroísmo. 87 pp.

Mifsud D, Audisio P (2008) The Kateretidae and Nitidulidae of the Maltesse Archipelago (Coleoptera). *Bulletin of the entomological society of Malta* 2008 (1): 15–37.

Mitter H, Schuh R (2008) *Catogenus rufus* (F.) - neu für Europa! (Coleoptera: Passandridae). *Koleopterologische Rundschau* 78: 329–332.

Moncoutier B (2001) Les "Clavicornes" de la faune de France (première partie). *Le Coléoptèriste* 43: 187–207.

Moncoutier B (2002) Les «Clavicornes» de la faune de France (deuxième partie). *Le Coléoptèriste* 5: 7–33.

Monzo C, Vanaclocha P, Outerelo R, Ruiz-Tapiador I, Tortosa D, Pina T, Castanera P, Urbaneja A (2005) Catalogación de especies de las familias Carabidae, Cicindelidae y Staphylinidae en el suelo de los cítricos de la provincia de Valencia, España. *Bol. San. Veg. Plagas* 31: 483–492.

Mouchet J, Giacomini T, Julvez J (1995) Spreading of disease vectors and pests throughout the world by man. *Cahiers d'Etudes et de Recherches Francophones/Sante* 5: 293–298.

Neculiseanu ZZ, and Matalin AV (2000) A catalogue of the ground-beetles of the Republic of Moldova (Insecta, Coleoptera, Carabidae). Pensoft, Bulgaria, Sofia. 164 pp.

Newton A: Staphylinini Species Catalog Draft. http://www.staphylinini.org/staphylinini/Products.html.

Ødegaard F, Tømmeras B (2000) Compost heaps - refuges and stepping-stones for alien arthropod species in northern Europe. *Diversity and Distributions* 6: 45–59.

Ortuno V, Toribio M (2005) Carabidae de la Peninsula Iberica y Baleares. Vol. 1. Trechinae, Bembidiini. Argania, Spain, Barcelona. 455 pp.

Paulian R (1988) Biologie des Coléoptères. Lechevalier, France, Paris. 719 pp.

Paulian R, Baraud J (1982) Lucanoidea et Scarabaeoidea. Lechevalier, France, Paris. 477 pp.

Peck SB (2009) The beetles of Barbados, West Indies (Insecta: Coleoptera): diversity, distribution and faunal structure. *Insecta Mundi* 73: 1–51.

Perrault GG (1981) Le genre *Lesitus* (Foehlig) (Col. Carabidae) III - le sous-genre *Nebrileistus* (Banninger). *Bulletin de la Société linnéenne de Lyon* 50 (7): 22–226.

Perrault GG (1984) New record of *Notobia (Anisotarsus) cupripennis* (Germar) (Coleoptera: Carabidae: Harpalini). *The Coleopterists Bulletin* 38 (4): 334.

Perrings C, Dehnen-Schmutz K, Touza J, Williamson M (2005) How to manage biological invasions under globalization. *Trends in Ecology & Evolution* 20: 212–215.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288.

Poland TM, McCullough DG (2006) Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* 104: 118–124.

Pollock DA, Ivie MA (1996) Anthicidae (Coleoptera) of the Virgin Islands. *Florida Entomologist* 79: 230–240.

Ratti E (2007) Silvanid beetles in Italy (Coleoptera Cucujoidea Silvanidae). *Bollettino del Museo Civico di Storia Naturale di Venezia* 58: 83–137.

Ratti E: Coleotteri alieni in Italia. http://www.msn.ve.it [accessed 25.05.2007].

Reemer M (2003) Invasieve Arthropoda in Nederland: een eerste inventarisatie. European Invertebrate Survey, Nederland, Leiden. 63 pp.

Reibnitz J, Schawaller W (2006) *Cynaeus angustus* (Leconte, 1851) (Coleoptera: Tenebrionidae), eine neue Adventivart in Mitteleuropa ? *Mitt. ent. V. Stuttgart* 41: 153–154.

Rogé J (2003) Prolifération de *Lispinus impressicollis* (Motschulsky, 1857) et de *Symbiotes gibberosus* (Lucas, 1846), hôtes d'un biotope particulier, dans le département de l'Aude (11) (Coleoptera, Staphylinidae et Endomychidae). *L'Entomologiste* 59 (3): 65–66.

Rücker WH (1995) *Cartodere australica* (Belon) und *Cartodere norvegica* (Strand) (Coleoptera: Latridiidae). *Mitt. internat. entomol. Ver.* 20: 59–61.

Ruiz GM, and Carlton JT (2003) Invasive species: vectors and management strategies. *In* Invasive species: vectors and management strategies. Island Press, USA, Washington. 518 pp.

Ruta R, Konwerski S, Fkrolik R, Lason A, Milkowski M (2006) New records of dermestid beetles (Coleoptera: Dermestidae) in Poland. Part 2. Megatominae. *Wiadomosci Entomologiczne* 25 (1): 21–28.

Ruta R, Konwerski S, Kadej M, Herrmann A, Lason A (2004) Three species of dermestid beetles (Coleoptera: Dermestidae) new to the Polish fauna with remarks on dermestids introduced to Poland. *Polskie Pismo Entomologiczne* 73: 307–314.

Ryndevich SK (2004) Review of species of the genus *Cercyon* Leach, 1817 of Russia and adjacent regions. I. Subgenus *Cercyon* (*s.str.*) Leach, 1817. *Cercyon lateralis*-group (Coleoptera: Hydrophilidae). *Annales Universitatis Mariae Curie-Sklodowska* 59: 1–13.

Santamaria JM, Gayoso A, Otero JC (1996) Los Laemophloeidae Ganglbauer, 1899 (Coleoptera) iberobaleares. Lista de especies y datos corologicos. *Boln. Asoc. esp. Ent.* 20 (3–4): 107–114.

Schaefer L (1949) Les Buprestides de France: tableaux analytiques des Coléoptères de la faune franco-rhénane, France, Rhénanie, Belgique, Hollande, Valais, Corse. Famille LVI. E. Le Moult, France, Paris . 511 pp.

Scheerpeltz O (1972) Studien an den paläarktischen Arten der Gattung *Myrmecopora* Saulcy (Col. Staphylinidae). *Koleopterologische Rundschau* 50: 93–109.

Schmitz H, Schmitz A, Trenner S, Bleckmann H (2002) A new type of insect infrared organ of low thermal mass. *Naturwissenschaften* 89: 226–229.

Schuh R, Mifsud D (2000) The cylindrical bark beetles of Malta (Insecta: Coleoptera: Zopheridae, Colydiinae). *Ann. Naturhist. Mus. Wien* 102B: 259–267.

Schulte GG, Elnitsky MA, Benoit JB, Denlinger DL, Lee RE (2008) Extremely large aggregations of collembolan eggs on Humble Island, Antarctica: a response to early seasonal warming? *Polar Biology* 31: 889–892.

Sefrova H (2005) Introduced and invasive insect species in the Czech Republic and their economic and ecological impact (Insecta). *Acta Univ. Agric. Silvic. Mendel. Brun.* 53 (17): 151–158.

Šefrova H, Lastuvka Z (2005) Catologue of alien animal species in the Czech Republic. *Acta Univ. Agric. Silvic. Mendel. Brun.* 53 (18): 151–170.

Serrano J, Lencina JL, Andujar A (2003) Distribution patterns of Iberian Carabidae (Insecta, Coleoptera). *Graellsia* 59 (2–3): 129–153.

Sharp D (1882–1887) Biologia centrali-americana. Insecta. Coleoptera. Vol. I. Part 2. Published for the editors by R.H. Porter, England, London. 824 pp.

Shockley FW (2009) Endomychidae. Handsome fungus beetles. http://tolweb.org/Endomychidae/9169/2009.03.31 [accessed 31.03.2009] In: The Tree of Life Web Project, http://tolweb.org/.

Shockley FW, Tomaszewska KW, McHugh JV (2009a) An annotated checklist of the handsome fungus beetles of the world (Coleoptera: Cucujoidea: Endomychidae). *Zootaxa* 1–113.

Shockley FW, Tomaszewska KW, and McHugh JV (2009b) Review of the natural history of the handsome fungus beetles (Coleoptera: Cucujoidea: Endomychidae). *Insecta Mundi* 72: 1–24.

Simberloff D (2001) Biological invasions - how are they affecting us, and what can we do about them? *Western North American Naturalist* 61: 308–315.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP, Ostoja-Starzewski JC, Collins DW (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology* 9: 307–326.

Soldati F (2007) Fauna of France and Corsica, Coleoptera Tenebrionidae (Alleculinae excluded). Systematic Catalogue and Atlas. *Mémoires de la Société Linnéenne de Bordeaux* 6: 1–186.

Sörensson M, Johnson C (2004) The first European records of the pantropical genus *Bambara* Vuillet, and a review of the immigrant featherwing beetles in Europe (Coleoptera: Ptiliidae). *Koleopterologische Rundschau* 74: 287–302.

Stoch F: Checklist of the species of the italian fauna. Version 2.0. http://www.checklist.faunaitalia.it [accessed 03.12.2003].

Streito JC, Martinez M (2008) Entomological actualities: new introduced pests insects (period January 2000 at June 2005). *7eme Conference Internationale sur les Ravageurs en Agriculture*, France, Montpellier, 26–27 octobre, 2008, unpaginated.

Tamisier J-P (2004) *Clambus simsoni* Blackburn, un petit coléoptère australien en pleine expansion en France (Coleoptera, Clambidae). *Bull. Société linnéenne de Bordeaux* 32 (1): 41–45.

Telnov D (1996) Sixty three new and rare species of Coleoptera in the fauna of Latvia. *Latvijas entomologs* 35: 36–43.

The World Factbook: Central Intelligence Agency, 2009. https://www.cia.gov/library/publications/the-world-factbook/index.html.

Théry A (1942) Coléoptères Buprestides. Lechevalier, France, Paris. 221 pp.

Thomas MC (1995) Invertebrate Pets and the Florida Department of Agriculture and Consumer Services. *Florida Entomologist* 78: 39–44.

Tomov R (2009) Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia. Pensoft, Bulgaria, Sofia. 112 pp.

Trautner J, Geigenmuller K (1987) Tiger beetles, ground beetles. Illustrated key to the Cicindelidae and Carabidae of Europe. TRIOPS Verlag, Margraf Distributor. Germany, Gaimersheim. 488 pp.

Tronquet M (2006) Catalogue iconographique des coléoptères des Pyrénées-Orientales. Association roussillonnaise d'entomologie, France, Perpignan. 78 pp.

Turin H, Penev L, Casale A (2003) The Genus *Carabus* in Europe. A synthesis. Pensoft, Sofia, Bulgaria. 511 pp.

Valemberg J (1997) Catalogue descriptif, biologique et synonymique de la faune Paléarctique des coléoptères Carabidae Latreille, 1806. Tome 1 Corpus. Mémoire de la Société Entomologique du Nord de la France, France, Villeneuve d'Ascq. 659 pp.

Vernon P, Caron F, Davies L (1999) Annual activity of two endemic beetles (Carabidae) at the edge between fell-field and moorland on a sub-Antarctic island. European *Journal of Soil Biology* 35: 39–43.

Vieira V, Borges P, Karsholt O, Wunderlich J (2003) The Arthropoda fauna of Corvo island (Azores): new records and updated list of species. *Vieraea* 31: 145–156.

Vincent R (1999) Une nouvelle fois un *Aridius* (Coléoptère Latridien) va-t-il envahir l'Europe ? (*Cartodere (Aridius) delamarei* Dajoz, 1962). *L'Entomologiste* 55 (2): 53–55.

Vorst O (2009) *Cercyon castaneipennis* sp. n., an overlooked species from Europe (Coleoptera: Hydrophilidae). *Zootaxa* 2054: 59–68.

Vorst O, Van Ee G, Huijbregts H, Van Nieuwenhuijzen A (2007) On some smaller Latvian Coleoptera. *Latvijas entomologs* 44: 15–25.

Weidner H, Rack G, Friedrichsen D (1984) Tables de détermination des principaux ravageurs des denrées entreposées dans les pays chauds. GTZ, Germany, schborn. 157 pp.

Wittenberg R, Kenis M, Blick T, Hanggi A, Gassmann A, Weber E (2006) Invasive alien species in Switzerland: an inventory of alien species and their threat to biodiversity and economy in Switzerland. Federal Office for the Environment (FOEN), Switzerland, Bern. 155 pp.

Yélamos T (1992) Data on Afrotropical Histendae (Coleoptera), with description of *Hister sindarae* n. sp. Misc. Zool. Barcelona 16: 37–43.

Zahradnik P, Mifsud D (2005) *Ozognathus cornutus* (LeConte) - new record for the Palaearctic Region (Coleoptera: Anobiidae). *Studies and reports of District Museum Prague-East, Taxonomical Series* 1(1–2): 141–143.

Table 9.5.1. List and characteristics of the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. Status: **A** Alien *to* Europe **C** Cryptogenic. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Acanthocnemidae								
Acanthocnemus nigricans (Hope 1845)	A	phyto-phagous	Australasia	1922, FR-COR	CY, FR, FR-COR, DE, IT, IT-SAR, IT-SIC, PT, ES	I2	timber, wood	Alonso-Zarazaga et al. (2003), (Kreiss et al. (2005)
Anobiidae								
Calymmaderus oblongus (Gorham, 1883)	A	phyto-phagous	Tropical, subtropical	Unknown	PT-AZO	J1	stored products	Bercedo et al. (2008), Borges et al. (2005), Espanol (1979), Mendonça and Borges (2009)
Epauloecus unicolor (Piller and Mitterpacher)	C	detriti-vorous	Crypto-genic	1861, DE	AT, BE, BA, BG, HR, CZ, DK, EE, FI, FR, FR-COR, DE, HU, IS, IE, IT, LV, LT, LU, MD, NL, NO, PL, PT, PT-AZO, RO, RU, RS, SK, SI, ES, SE, CH, UA, GB	J1	barns, cowsheds, animal burrows	Tomov (2009), Wittenberg et al. (2006)
Ernobius mollis (Linnaeus, 1758)	C	phyto-phagous	Crypto-genic	Unknown	PT-AZO	J, G	soft wood, sawmills, books	Borges et al. (2005), Espanol (1992), Mendonça and Borges (2009)
*Gibbium aequinoctia*le Boieldieu, 1854	A	detriti-vorous	Tropical, subtropical	Unknown	MT	J1	stored products	Bellés and Halstead (1985)
Gibbium psylloides (Czempinski, 1778)	C	detriti-vorous	Crypto-genic	1900, CZ	AL, AT, BE, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, HU, IE, IT, IT-SAR, IT-SIC, MT, MD, NL, PL, PT, PT-MAD, RO, RU, RS, SK, ES, ES-BAL, SE, CH, UA, GB	J1	houses, hotels, stored products	Bellés (1985), Bellés and Halstead (1985), Duff (2008), Freude et al. (1969), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Lasioderma sericorne Fabricius, 1792	A	phyto-phagous	Tropical, subtropical	1848, PT	AL, AT, BG, CZ, DK, EE, HU, IT, IT-SAR, IT-SIC, LV, MT, PT, RS, CH	J1	tobacco, stored products	Borges et al. (2005), Espanol (1992), Freude et al. (1969), Glavendekic et al. (2005), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Mezium affine Boieldieu 1856	C	detriti-vorous	Crypto-genic	Unknown	AT, DK, DE, PT-AZO, PT-MAD, ES, ES-CAN, SE	J	mills, stored products, bird nests	Bellés (1985), Freude et al. (1969)
Mezium americanum Laporte de Castelnau, 1840	A	detriti-vorous	North America	Unknown	IT, IT-SAR, MT, PT-AZO	J	stored products	Bellés (1985), Borges et al. (2005)
Nicobium castaneum (Olivier, 1790)	C	phyto-phagous	Crypto-genic	1807, PT	AT, BA, HR, CY, CZ, FR, FR-COR, DE, GR, IT, IT-SAR, IT-SIC, MT, PL, PT, PT-AZO, PT-MAD, RO, SI, ES, ES-BAL, ES-CAN, CH, UA	J	soft wood furniture, old books	Espanol (1992), Freude et al. (1969), Mendonça and Borges (2009), Šefrova and Lastuvka (2005)
Ozognathus cornutus (LeConte, 1859)	A	detriti-vorous	North America	2005, ES	MT, RO, ES	J	dead wood	Allemand (2008), Bercedo et al. (2005), Zahradnik and Mifsud (2005)
Pseudeurostus hilleri (Reitter 1877)	A	detriti-vorous	Asia-Temperate	1993, DE	DK, DE	J	likely scavenger and inhabitant of residues, potential minor pest of feed mills and warehouses	
Ptilineurus marmoratus (Reitter, 1877)	A	phyto-phagous	Asia	1999, FR	FR, SE	G	trees	Imperial Institute of Entomology (1930)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ptinus bicinctus Sturm 1837	C	detriti-vorous	Crypto-genic	1856, FR	AT, BY, BE, BA, BG, HR, CZ, DK, EE, FI, FR, FR-COR, DE, HU, IT, IT-SAR, LV, NL, NO, PL, RO, RU, RS, SK, SI, ES, SE, CH, UA	J1	stored products	Freude et al. (1969)
Ptinus clavipes Panzer, 1792	C	detriti-vorous	Crypto-genic	Unknown	EE, LV, MT, ES-CAN, GB	J1	stored products, fur	Duff (2008), Freude et al. (1969), Machado and Oromi (2000)
Ptinus fur (Linnaeus 1758)	C	detriti-vorous	Crypto-genic	1940, BG	AL, AD, AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FÖ, FI, FR, FR-COR, DE, GR, HU, IS, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, LU, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SK, SI, ES, ES-BAL, ES-CAN, SE, CH, UA, GB	J1, J6	waste, dried vegetals	Bengtson (1981), Borges et al. (2005), Duff (2008), Mendonça and Borges (2009), Tomov (2009)
Ptinus latro Fabricius, 1775	C	detriti-vorous	Crypto-genic	1850, CZ	AL, AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, HU, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, LU, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, SK, SI, ES, ES-CAN, SE, CH, UA, GB	J	old wood, synanthropic	Borges et al. (2005), Freude et al. (1969), Šefrova and Lastuvka (2005), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ptinus tectus Boieldieu 1856	A	detriti-vorous	Australasia	1916, DE	AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FÖ, FI, FR, DE, GR, HU, IE, IT, LV, LT, LU, MD, NL, NO, PL, PT, PT-AZO, RU, RS, SK, SI, ES, SE, CH, UA, GB	J1	stored products	Allemand (2008), Bengtson (1981), Duff (2008), Wittenberg et al. (2006)
Tricorynus tabaci (Guérin-Méneville, 1850)	A	phyto-phagous	C & S America	1965, CZ	HR, CZ, DK, FR, DE, IT	J	seeds, stored products; crataegus in native fields	Freude et al. (1969), Šefrova and Lastuvka (2005)
Trigonogenius globulus Solier, 1849	A	detriti-vorous	C & S America	1939, CZ	CZ, DK, GB	J	dried animal products, insects, herbarium, stored products	Duff (2008), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005)
Anthicidae								
Anthicus crinitus La Ferte-Senectere, 1849	A	unknown	Asia	Unknown	CY, GR, GR-SEG, MT, PT-MAD	J	anthropophilous, larva scavenger	Pollock and Ivie (1996)
Anthicus czernohorskyi Pic, 1912	A	unknown	Asia	1982, IT	IT	U		Degiovanni and Pezzi (2007)
Omonadus floralis (Linnaeus 1758)	A	detriti-vorous	Asia-Tropical	1951, HR, BG	AL, AT, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, GR-ION, GR-SEG, HU, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SK, ES, ES-BAL, ES-CAN, SE, CH	J6	vegetal decay, detritiphage, mycophage, adult predator	Freude et al. (1969), Hemp and Dettner (2003), Machado and Oromi (2000), Mendonça and Borges (2009), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Stricticomus tobias (De Marseul 1879)	A	detriti-vorous	Asia	1944, IT	AT, BY, BE, CZ, DK, EE, FR, FR-COR, DE, HU, IT, IT-SAR, IT-SIC, LV, LT, MT, MD, NL, PT, PT-MAD, SK, ES, ES-CAN, SE, CH, GB	I, J1	rotten vegetal tissues	Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Telnov (1996), Wittenberg et al. (2006)
Aphodiidae								
Aphodius gracilis Boheman, 1857	A	detriti-vorous	Africa	Unknown	PT-AZO	E	dung	Baraud (1985)
Saprosites mendax Blackburn, 1892	A	detriti-vorous	Australasia	1921, GB	GB	I2	rotting wood; in borings of *Dorcus* and *Sinodendron* beetles	Baraud (1992), Duff (2008), Paulian and Baraud (1982)
Saprosites natalensis (Peringuey, 1901)	A	detriti-vorous	Africa	1982, GB	GB	I2	rotting wood	Duff (2008)
Tesarius caelatus (Laconte, 1857)	A	detriti-vorous	North America	1976, GB	GB	U		Baraud (1992), Duff (2008)
Bostrichidae								
Apate monachus Fabricius, 1775	A	phyto-phagous	Tropical, subtropical	Unknown	FR, FR-COR, IT-SAR, IT-SIC, ES	G3, I2	polyphagous stem borer, fruit trees, Acacia	Freude et al. (1969), Lesne (1901)
Bostrychoplites cornutus (Olivier 1790)	A	phyto-phagous	Africa	Unknown	DK, DE, IT, ES, SE	J	timber (ethnic carved wooden bowls and ornaments)	Freude et al. (1969), Ratti. Coleotteri alieni in Italia.)
Dinoderus bifoveolatus (Wollaston, 1858)	A	phyto-phagous	Tropical, subtropical	Unknown	AT, BE, HR, DK, DE, NL, PT-MAD, SK, ES, SE, CH, GB	J	bamboo borer (N); dried cassava chips and stored products	Duff (2008), Freude et al. (1969), Lesne (1901)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Dinoderus minutus (Fabricius, 1775)	A	phyto-phagous	Tropical, subtropical	1965, CZ	AL, BE, CZ, DK, FR, DE, GR, IT, IT-SAR, IT-SIC, NL, PL, SK, SE, GB	J,I2	bamboo, manioc (Cassava), stored products (intro)	Duff (2008), Freude et al. (1969), Lesne (1901),Lesne (1904), Šefrova and Lastuvka (2005)
Rhyzopertha dominica (Fabricius, 1792)	A	phyto-phagous	Asia-Tropical	1900, CZ	AL, AT, BY, BE, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-SEG, IE, IT, IT-SAR, IT-SIC, LV, MT, NL, PL, PT, PT-AZO, RO, SK, ES, ES-BAL, ES-CAN, SE, CH, GB	J1	stored products, mainly cereals	Borges et al. (2005), Cobos (1986), Duff (2008), Freude et al. (1969), Lesne (1901), Lesne (1904), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Sinoxylon senegalense Karsch, 1831	A	phyto-phagous	Africa	Unknown	DE	J	*Acacia* wood borer (N); imported construction wood	Lesne (1901)
Heterobostrychus hamatipennis (Lesne, 1895)	A	phyto-phagous	Asia	2005, BE	BE	J	xylophagous, Salix, osier goods	Lesne (1901)
Buprestidae								
Agrilus planipennis Fairmaire, 1888	*A*	phyto-phagous	Asia	2003	RU	I2	*Fraxinus*	Baranchikov et al. (2008)
Buprestis decora Fabricius, 1775	A	phyto-phagous	North America	Unknown	ES-CAN	I2		Cobos (1986), Machado and Oromi (2000)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Chrysobothris dorsata (Fabricius, 1787)	A	phyto-phagous	Africa	1986, ES	ES	F5, I		Ratti. Coleotteri alieni in Italia.)
Carabidae								
Laemostenus complanatus (Dejean, 1828)	A	parasitic/predator	Africa	Unknown	FR, FR-COR, IE, PT-AZO, ES-CAN, GB	B, J, H1	littoral in ports, cellars caves	Anderson et al. (2000), Arndt (2006), Borges et al. (2005), Duff (2008), Jeannel (1942), Luff (1998), Luff (2007), Machado (1976), Machado and Oromi (2000), Mendonça and Borges (2009), Perrault (1981), Perrault (1984)
Leistus nubivagus Wollaston, 1864	A	parasitic/predator	Africa	Unknown	ES-CAN	U		Machado (1976), Machado and Oromi (2000), Perrault (1981)
Notiobia cupripennis (Germar, 1824)	A	phyto-phagous	C & S America	Unknown	ES-CAN	I2	seeds of Amaranthus	Machado and Oromi (2000), Perrault (1984)
Plochionus pallens (Fabricius, 1775)	A	parasitic/predator	C & S America	2000, NL	DK, FR, DE, HU, IT, NL	J	in ports, transported with peanuts, raisin storages	Trautner and Geigenmuller (1987), Valemberg (1997)
Pterostichus caspius (Ménétriés, 1832)	A	parasitic/predator	Asia-Temperate	1980, CZ	BG, CZ	U	Predator in various environments, pyrophilous	Hurka (1996), (Šefrova and Lastuvka (2005), Valemberg (1997)
Somotrichus unifasciatus (Dejean, 1831)	A	parasitic/predator	Africa	Unknown	FR, IT	J	predator of beetles in stored products, avian droppings	Jeannel (1942), (Valemberg (1997)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trechicus nigriceps (Dejean, 1831)	A	parasitic/ predator	Asia-Tropical	1902, DE	AT, BE, BA, BG, HR, CZ, DK, FI, FR, DE, HU, IT, LV, LI, LU, MD, NL, NO, PL, PT-AZO, PT-MAD, RS, SK, SI, ES, ES-CAN, SE, CH, UA, GB	I1, I2, J1, J6	compost, predator, gardens; also in peanuts	Borges et al. (2005), Darlington (1964), Duff (2008), Hurka (1996), Luff (2007), Machado and Oromi (2000), Mendonça and Borges (2009), Neculiseanu and Matalin (2000), Serrano et al. (2003), Tomov (2009), Trautner and Geigenmuller (1987), Valemberg (1997), Wittenberg et al. (2006)
Cerylonidae								
Murmidius ovalis (Beck 1817)	A	detriti-vorous	Asia	Unknown	AL, AT, DK, FR, DE, HU, IT, PL, CH, GB	J1	stored products (few damage-ports)	Duff (2008), Wittenberg et al. (2006), Moncoutier (2002)
Philothermus montandoni Aube, 1843	A	detriti-vorous	Tropical, subtropical	Unknown	FR, IT	X11	botanical garden	Stoch: Checklist of the species of the italian fauna)
Ciidae								
Xylographus bostrychoides (Dufour 1843)	A	detriti-vorous	Asia?	Unknown	AT, BY, BA, BG, HR, CZ, DK, FR, FR-COR, GR, HU, IT, IT-SAR, IT-SIC, PL, RO, SK, ES, UA	I	feeds on fungi	Tomov (2009)
Clambidae								
Clambus simsoni Blackburn 1902	A	detriti-vorous	Australasia	1987, SE	AT, FR, DE, NL, SE, GB	G	forest, firewood, compost; myco-phagous	Duff (2008), Tamisier (2004)

Family species	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Cleridae								
Necrobia ruficollis (Fabricius 1775)	C	parasitic/ predator	Crypto-genic	1976, LT	AT, DK, EE, FI, HU, LT, NO, PT-AZO, SE, CH	J1, J6	predator on old bones, decaying animals	Borges et al. (2005), Du Chatenet (2000), Freude et al. (1979), Mendonça and Borges (2009), Wittenberg et al. (2006)
Necrobia rufipes (De Geer 1775)	A	parasitic/ predator	Tropical, subtropical	1935, LT	AT, BG, DK, EE, FI, DE, LT, NO, PT, PT-AZO, SE, CH	J1, J6	predator, necrophage, seeds with oil content (copra, soya), dried fish	Borges et al. (2005), Du Chatenet (2000), Freude et al. (1979), Haines and Rees (1989), Tomov (2009), Wittenberg et al. (2006)
Necrobia violacea (Linnaeus 1758)	C	parasitic/ predator	Crypto-genic	1976, LT	AT, DK, FI, HU, LT, NO, SE, CH	J1, J6	old bones, prey dry carrion	Freude et al. (1979), Wittenberg et al. (2006)
Opetiopalpus scutellaris (Panzer 1797)	A	parasitic/ predator	Africa	Unknown	AT, EE, FR, DE, ES	J	old timber houses	Du Chatenet (2000), Freude et al. (1979)
Paratillus carus (Newman, 1840)	A	parasitic/ predator	Australasia	1933, GB	FR, GB	G,I2	predator on Lyctiidae	Du Chatenet (2000), Duff (2008)
Tarsostenus univittatus (Rossi, 1792)	C	parasitic/ predator	Crypto-genic	1990, CZ	AT, CZ, CH	J	predator on Bostrychidae, Anobiidae	Du Chatenet (2000), Freude et al. (1979), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Thaneroclerus buqueti (Lefebvre, 1835)	A	parasitic/ predator	Asia	1963, CZ	CZ, DE, IT, PL	J	predator on insects on tobacco, rice (*Lasioderma*, *Areaocerus*)	Du Chatenet (2000), Freude et al. (1979), Šefrova and Lastuvka (2005)
Corylophidae								
Orthoperus aequalis Sharp 1885	A	detriti-vorous	Australasia	Unknown	HR, FR, FR-COR, IT, PT-AZO, PT-MAD, ES, ES-CAN, CH, GB	G, I2		Borges et al. (2005), Bowestead (1999), Duff (2008), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia.)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptophagidae								
Atomaria lewisi Reitter, 1877	A	detriti-vorous	Asia	1937, GB	AL, AT, BY, BE, HR, CZ, DK, EE, FI, DE, IT, LV, LT, MD, NO, PL, PT-AZO, SK, SE, CH, UA, GB	I2, J1, G	mycophage; compost, In decaying plant material	Duff (2008), Freude et al. (1967), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Caenoscelis subdeplanata C.Brisout de Barneville, 1882	A	detriti-vorous	North America	1950, GB	BY, HR, CZ, EE, FI, FR, FR-COR, DE, IT, LV, LT, LU, MT, MD, NL, NO, PL, PT-MAD, RU, SI, ES, ES-CAN, SE, CH, UA, GB	G, X11, I2, FB	mycophage; forests In decaying wood and plant material	Duff (2008), Falcoz (1929), Freude et al. (1967), Ratti. Coleotteri alieni in Italia., Tomov (2009), Wittenberg et al. (2006)
Cryptophagus acutangulus Gyllenhall, 1828	C	detriti-vorous	Crypto-genic	1956, BG	AL, AT, BY, BE, BA, BG, CZ, DK, EE, FI, FR, DE, IT, LV, LT, PL, RO, RS, SK, SI, SE, CH, UA, GB	J	attic, mills	Falcoz (1929), Freude et al. (1967), Tomov (2009)
Cryptophagus affinis Sturm 1845	C	detriti-vorous	Crypto-genic	1956, BG	AL, BG, CZ, FR, GR, IT, IT-SIC, LV, MT, PT-AZO, PT-MAD, RO, ES-CAN, GB	J	fungi, dry fruits	Borges et al. (2005), Duff (2008), Falcoz (1929), Freude et al. (1967), Machado and Oromi (2000), Mendonça and Borges (2009), Tomov (2009)
Cryptophagus cellaris (Scopoli, 1763)	C	detriti-vorous	Crypto-genic	1939, PT	AL, AT, BY, BE, BA, BG, HR, CZ, DK, FI, FR, DE, GR, HU, IT, IT-SIC, LV, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, SK, SI, ES-CAN, SE, CH, UA, GB	J	mycophagous, stored products, herbariums, insects	Borges et al. (2005), Duff (2008), Falcoz (1929), Freude et al. (1967), Machado and Oromi (2000), Moncoutier (2002), Tomov (2009)

Family species	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Cryptophagus fallax Balfour-Browne, 1953	C	detriti-vorous	Crypto-genic	1900, CZ	AL, AT, BY, BE, BA, BG, CZ, DK, EE, FI, FR, DE, IE, IT, IT-SIC, LV, LT, MT, NL, PL, RO, RS, SK, SI, SE, CH, UA, GB	J1	stored products	Duff (2008), Freude et al. (1967), Šefrova and Lastuvka (2005), Tomov (2009)
Cryptophagus pilosus Gyllenhal 1828	C	detriti-vorous	Crypto-genic	1956, BG	BY, BG, FÖ, FR, LV, PT-AZO, PT-MAD	J1	attic	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009)
Cryptophagus subfumatus Kraatz, 1856	C	detriti-vorous	Crypto-genic	1956, BG	AD, AT, BY, BE, BA, BG, CZ, DK, EE, FI, FR, FR-COR, DE, IT, IT-SAR, LV, LT, MD, NL, NO, PL, PT-AZO, PT-MAD, SK, SI, ES-CAN, SE, CH, UA, GB	J1	dry fruits, nuts	Duff (2008), Falcoz (1929), Freude et al. (1967), Tomov (2009)
Curelius japonicus (Reitter, 1877)	C	detriti-vorous	Crypto-genic	1997, IT	DE, IT, MT, ES, ES-CAN	U	probably a fungus feeder	Peck (2009)
Henoticus californicus (Mannhereim 1843)	A	detriti-vorous	North America	Unknown	BY, BE, DK, FR, DE, NL, SE, GB	J1	stored products	Duff (2008), Falcoz (1929), Freude et al. (1967), Ratti. Coleotteri alieni in Italia.)
Cybocephalidae								
Aglyptinus agathidioides Blair 1930	A	parasitic/ predator	Africa	1912, GB	ES-CAN, GB	G, F,I2, J	potters bar	Duff (2008), Machado and Oromi (2000)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cybocephalus nipponicus Endrody-Younga, 1971	A	parasitic/ predator	Asia-Temperate	2002, IT	IT	J100	predator of scales	Evans et al. (2005), Lupi (2002), Ratti. Coleotteri alieni in Italia.)
Dermestidae								
Anthrenocerus australis (Hope, 1843)	A	detriti-vorous	Australasia	1933, GB	FR, NL, GB	J1	clothes	Duff (2008), Freude et al. (1979), Hava (2003), Hava. A Catalogue of World Dermestidae., Reemer (2003)
Anthrenus caucasicus Reitter, 1881	A	detriti-vorous	Asia	1941, LV	AT, LV, PL	J1, I2, E	larva scavenger; adult on flowers	Freude et al. (1979), Hava. A Catalogue of World Dermestidae., Ruta et al. (2004)
Anthrenus flavidus Solsky, 1876	A	detriti-vorous	Asia	1935, PL	DE, PL	J1, E	wood, paper, leather and woven fabrics in collections in museums	Freude et al. (1979), Hava. A Catalogue of World Dermestidae.)
Anthrenus flavipes LeConte, 1854	C	detriti-vorous	Crypto-genic	1955, PL	BG, CZ, DK, IT-SAR, IT-SIC, PL, CH, GB	J1, G	domestic, feeds on furnitures, fabrics, etc., adult pollinophage; larva necro-phagous (faeces, cadavers, pine processionnary nests)	Duff (2008), Freude et al. (1979), Hava (2003), Hava. A Catalogue of World Dermestidae., Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Anthrenus oceanicus Fauvel, 1903	A	detriti-vorous	Australasia	2004, CZ	CZ, MT	J1, E	stored products	Hava (2003), Hava. A Catalogue of World Dermestidae., Šefrova and Lastuvka (2005)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Attagenus diversepubescens Pic, 1936	A	detriti-vorous	C & S America	Unknown	DE	J	stored products	Hava (2003)
Attagenus fasciatus (Thunberg, 1795)	C	detriti-vorous	Crypto-genic	1927, DE	BG, DE, IT, MT, GB	J1, J6	necrophagous, in vegetal	Duff (2008), Freude et al. (1979), Hava (2003), Ratti. Coleotteri alieni in Italia., Tomov (2009)
Attagenus gobicola Frivaldszky, 1892	A	detriti-vorous	Asia-Temperate	Unknown	SE	J	stored products	Hava (2003)
Attagenus lynx (Mulsant & Rey, 1868)	A	detriti-vorous	Asia-Temperate	Unknown	PL	J	stored products	Hava (2003)
Attagenus smirnovi Zhantiev, 1973	C	detriti-vorous	Crypto-genic	1973, RU	BY, CZ, DK, LV, NO, PL, RU, CH, GB	J1	pest of animal-origin material (skin, furs, wool) but also buildings, entomological collections	Barsevskis et al. (2004), Duff (2008), Hava (2003), Ruta et al. (2004), Šefrova and Lastuvka (2005)
Attegenus unicolor Brahm 1791	C	detriti-vorous	Crypto-genic	1978, GB	BG, CZ, DK, LV, PL, CH, GB	J1, J6, E	domestic, feeds mainly on fabrics, adult pollinophage; larva necrophagous and cereals	Borges et al. (2005), Duff (2008), Freude et al. (1979), Hava (2003), Hermann and Baena (2004), Kadej (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Dermestes ater De Geer 1774	C	detriti-vorous	Crypto-genic	1868, GB	AT, BG, EE, FR, DE, LT, MT, PL, PT-AZO, ES-CAN, CH, GB	J1, J6	necrophagous	Duff (2008), Freude et al. (1979), Haines and Rees (1989), Hava (2003), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Dermestes bicolor Fabricius, 1781	A	detriti-vorous	Asia-temperate	Unknown	ES-CAN	J	stored products	Freude et al. (1979), Hava (2003), Machado and Oromi (2000)
Dermestes carnivorus Fabricius, 1775	A	detriti-vorous	C & S America	1919, PL	BE, FR, IE, PL, GB	J1, J6, G	necrophagous in houses, bird nests, dead fish	Freude et al. (1979), Haines and Rees (1989), Hava. A Catalogue of World Dermestidae.)
Dermestes coronatus Steven 1808	A	detriti-vorous	Asia	Unknown	PL	E	grasslands	Hava (2003)
Dermestes frischi Kugelann, 1792	C	detriti-vorous	Crypto-genic	1862, GB	BG, DK, EE, FR, IE, LV, LT, PT-AZO, GB	J1, J6	domestic	Borges et al. (2005), Duff (2008), Freude et al. (1979), Haines and Rees (1989), Hava (2003), Hava. A Catalogue of World Dermestidae., Mendonça and Borges (2009), Tomov (2009)
Dermestes lardarius (Linnaeus, 1758)	C	detriti-vorous	Crypto-genic	1880, BG	BG, DK, EE, FR, HU, LT	J1, J6	necrophagous but in vegetal matters (peanuts, corn), eggs predation	Camerini (2009), Freude et al. (1979), Haines and Rees (1989), Hava (2003), Hava. A Catalogue of World Dermestidae., Tomov (2009)
Dermestes leechi Kalík, 1952	A	detriti-vorous	Asia	Unknown	ES, GB	J	crushed bones	Duff (2008), Hava (2003), Hava. A Catalogue of World Dermestidae.)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Dermestes maculatus De Geer, 1774	C	detriti-vorous	Crypto-genic	1871, PL	AL, AT, BG, FR, IE, LT, MT, PL, PT, PT-AZO, CH, GB	J1, J6	domestic, on animal products, fabrics, necrophagous but in vegetal matter(corn kernels)	Borges et al. (2005), Duff (2008), Freude et al. (1979), Haines and Rees (1989), 88180, Wittenberg et al. (2006)
Dermestes peruvianus Laporte de Castelnau, 1840	A	detriti-vorous	C & S America	1919, PL	AT, CZ, FR, DE, IT, PL, ES-CAN, CH, GB	J1, J6, G	domestic, on animal products, fabrics;, necrophagous but in vegetal matter (corn kernels)	Freude et al. (1979), Haines and Rees (1989), Hava (2003), Machado and Oromi (2000), Šefrova and Lastuvka (2005)
Dermestes vorax Motschulsky, 1860	A	detriti-vorous	Asia-Temperate	Unknown	IT	J	detrivorous	Freude et al. (1979), Hava (2003)
Novelsis horni (Jayne, 1882)	A	detriti-vorous	C & S America	Unknown	NL	J		Hava (2003), Hava. A Catalogue of World Dermestidae.)
Orphinus fulvipes Guerin-Meneville 1838	A	detriti-vorous	Tropical, subtropical	Unknown	FR, GB	J	stored products	Duff (2008), Freude et al. (1979), Hava (2003)
Phradonoma tricolor (Arrow, 1915b:431)	A	detriti-vorous	Asia-Tropical	Unknown	DK, NL	J		Hava (2003), Hava. A Catalogue of World Dermestidae.)
Reesa vespulae (Milliron, 1939)	A	detriti-vorous	North America	1977, GB	CZ, DK, EE, FR, DE, IT, LV, NO, SE, CH, GB	J1	domestic places and in museum collections	Duff (2008), Freude et al. (1979), Hava (2003), Martinez and Cocquempot (1985), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Sefrania bleusei Pic 1899	A	detriti-vorous	Africa	1998, PL	FR, PL	J1, J6	fish bones, window sills, entomological collections	Beal and Kadej (2008), Hava (2003), Hava. A Catalogue of World Dermestidae., Ruta et al. (2004)
Telopes heydeni Reitter 1875	A	detriti-vorous	Africa	Unknown	FR	J1		Freude et al. (1979), Hava (2003)
Thaumaglossa rufocapillata Redtenbacher, 1867	A	parasitic/ predator	Asia, Africa	Unknown	DE, NL	U	egg cases of mantids	Freude et al. (1979), Hava (2003)
Thorictodes heydeni Reitter, 1875	C	detriti-vorous	Crypto-genic	1958, IT	IT	J1	stored seeds, peanuts	Ratti. Coleotteri alieni in Italia., Freude et al. (1979), Hava (2003)
Thylodrias contractus Motschulsky, 1839	A	detriti-vorous	Asia-Temperate	1935, IT	FR, IT, GB	J1	animal materials	Duff (2008), Šefrova and Lastuvka (2005), Freude et al. (1979), Hava (2003)
Trogoderma angustum (Solier, 1849)	A	detriti-vorous	C & S America	1921, PL	AT, CZ, DK, DE, LV, LT, PL, SE, CH	J1	domestic situations and in museum collections	Barsevskis et al. (2004), Freude et al. (1979), Hava (2003), Ruta et al. (2006), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Trogoderma glabrum (Herbst, 1783)	C	detriti-vorous	Crypto-genic	1904, BG	AT, BG, DK, FR, LV, LT, CH, GB	J1	domestic situations and in nests of solitary wasps	Duff (2008), Freude et al. (1979), Hava (2003), Tomov (2009), Wittenberg et al. (2006)
Trogoderma granarium Everts, 1898	A	detriti-vorous	Asia	1895, GB	AL, AT, BG, CZ, DK, DE, HU, IE, IT, IT-SAR, IT-SIC, PL, CH, GB	J1	stored products, especially cereals	Duff (2008), Freude et al. (1979), Hava (2003), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trogoderma inclusum LeConte, 1854	A	detritivorous	North America	1956, GB	AL, IT, PL, GB	J1	psychophage, stored products	Duff (2008), Hava (2003), Hermann and Baena (2004), Ratti. Coleotteri alieni in Italia.)
Trogoderma insulare Chevrolat, 1863	A	detritivorous	C & S America	Unknown	FR	J	stored products	Hava (2003)
Trogoderma longisetosum Chao & Lee, 1966	A	detritivorous	Asia	2005, CZ	AL, CZ	J1	stored products	Hava (2003), Hava. A Catalogue of World Dermestidae., Šefrova and Lastuvka (2005)
Trogoderma megatomoides Reitter, 1881	A	detritivorous	C & S America	1900, CZ	AL, AT, CZ, FR, IT, NL, SE	J1	insects in collection	Freude et al. (1979), Hava (2003), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005)
Trogoderma variabile Ballion, 1878	A	detritivorous	Asia	1978, GB	CZ, FI, IT, LV, SE, GB	J1	wheat, any dry vegetal and animal stored products in warehouse; major pest	Duff (2008), Hava (2003), Hava. A Catalogue of World Dermestidae., Šefrova and Lastuvka (2005), Ratti. Coleotteri alieni in Italia.)
Trogoderma versicolor (Creutzer, 1799)	C	detritivorous	Cryptogenic	Unknown	AT	J	eggs predation	Camerini (2009), Freude et al. (1979)
Dytiscidae								
Megadytes costalis Fabricius, 1775	A	parasitic/predator	C & S America	Unknown	GB	U	predator	Duff (2008)
Elateridae								
Cardiophorus taylori Cobos, 1970	A	phytophagous	Africa	1952, DE	DE	U	unknown	
Conoderus posticus (Eschscholtz)	A	phytophagous	C & S America	Unknown	PT-AZO	U	*Chrysanthemoides monilifera*	Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Panspaeus guttatus Sharp, 1877	A	phyto-phagous	Australasia	1981, GB	GB	U	unknown	Duff (2008), Freude et al. (1979)
Endomychidae								
Holoparamecus caularum Aube, 1843	C	detriti-vorous	Crypto-genic	1937, FR, FR-COR	AT, BG, FR, FR-COR, DE, CH	I, J, J6	on fungus, on decaying plant material, attic	Borges et al. (2005), Moncoutier (2002), Shockley et al. (2009a), Tomov (2009)
Holoparamecus depressus Curtis, 1833	C	detriti-vorous	Crypto-genic	1843, FR	DK, FR	J, J6	flour, dry fruits, medicinal plants, decayed wood	Curtis (1836), Shockley et al. (2009a)
Erotylidae								
Dacne picta Crotch, 1873	A	detriti-vorous	Asia	1954, FR-COR	AL, CZ, FR, FR-COR, IT, PL, ES	J	shitake mushrooms	Iablokoff-Khnzorian (1975), Šefrova and Lastuvka (2005)
Histeridae								
Carcinops pumilio (Erichson, 1834)	C	parasitic/ predator	Crypto-genic	1995, LT	AT, BG, DE, LV, LT, PT-AZO, CH	E	cadavers, faeces, *Dracunculus*	Borges (1990), Borges et al. (2005), Freude et al. (1971), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Carcinops troglodytes (Paykull, 1811)	A	parasitic/ predator	C & S America	Unknown	PT-AZO	J	predator on *Tribolium*, *Sitophilus* in manioc, poultry fly predator	Borges et al. (2005)
Chalcionellus decemstriatus Reichardt, 1932	A	parasitic/ predator	Africa	Unknown	FR	E	feces, cadavers	Freude et al. (1971), Gomy (2006), Gomy (2008), Gomy (2009)
Diplostix mayeti (Marseul, 1870)	A	parasitic/ predator	Africa	Unknown	FR	I2	predator under bark and pods, peanuts, manioc	Delobel and Tran (1993), Yélamos (1992)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Hister bipunctatus Paykull, 1811	A	parasitic/ predator	Africa	1974, FR	CY, FR, ES	E	dung	
Hypocaccus brasiliensis (Paykull, 1811)	C	parasitic/ predator	Crypto-genic	Unknown	IT, PT-AZO	B1	cadavers, faeces, sandy soil	Mendonça and Borges (2009)
Paromalus luderti Marseul, 1862	A	detriti-vorous	C & S America	Unknown	FR, ES, ES-CAN	I	decaying *Opuntia* in native range; straw and manure in invaded area	Gomy (2008), Machado and Oromi (2000)
Saprinus lugens Erichson, 1834	A	detriti-vorous	North America, C & S America	1984, IT	HR, FR, IT, IT-SAR, IT-SIC, PT, ES	H	cadavers, faeces	Ratti. Coleotteri alieni in Italia.)
Hydrophilidae								
Cercyon inquinatus Wollaston, 1854	A	unknown	Africa	Unknown	AT, HR, CZ, IT, PT-AZO, ES-CAN	U	decomposing seaweed, rotting fruits, cave guano	Borges et al. (2005), Boukal et al. (2007), Machado and Oromi (2000), Ryndevich (2004)
Cercyon laminatus Sharp, 1873	A	parasitic/ predator	Asia-Temperate	1950, CZ, IT	AL, AT, BE, CZ, DK, EE, FI, FR, DE, IT, LT, NL, ES, SE, CH, GB	E3, F9, I	compost, predator, In various humid environments; wet grasslands	Duff (2008), Freude et al. (1971), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Wittenberg et al. (2006)
Cercyon nigriceps (Marsham, 1802)	A	parasitic/ predator	Asia?	Unknown	CZ, PT-AZO	U		Borges et al. (2005), Boukal et al. (2007), Freude et al. (1971), Mendonça and Borges (2009), Ryndevich (2004)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptopleurum subtile Sharp, 1884	A	parasitic/ predator	Asia-Temperate	1950, IT	AL, AT, BE, CZ, DK, FI, FR, DE, HU, IT, NL, NO, SE, CH, GB	E3, F9, I	compost, predator, In various humid environments	Duff (2008), Freude et al. (1971), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Dactylosternum abdominale (Fabricius, 1792)	A	parasitic/ predator	Africa	Unknown	HR, CY, FR, DE, GR, IT, PT-AZO, PT-MAD, ES, ES-CAN	C1+C2	thermophilic, standing water with plants; egg predator on banana weevil in Kenya	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Oosternum sharpi Hansen, 1999	A	unknown	North America	Unknown	PT-AZO	C1, D	in standing water	Borges et al. (2005), Mendonça and Borges (2009), Peck (2009)
Pachysternum capense (Mulsant, 1894)	A	unknown	Africa	Unknown	GR, IT, ES-CAN	C1, D	in standing water	Boukal et al. (2007), Fikacek and Boukal (2004), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia.)
Pelosoma lafertei Mulsant, 1844	A	unknown	C & S America	1929, IT	FR, IT	D1-D4 ? J?	plant held waters, or phytotelmata	Fikacek and Boukal (2004), Sharp (1882–1887)
Laemophloeidae								
Cryptolestes duplicatus (Waltl 1834)	C	detriti-vorous	Crypto-genic	1990, FR	AT, BY, CZ, DK, FR, DE, HU, PL	J1, G1	under oak bark, stored products	Santamaria et al. (1996)
Cryptolestes ferrugineus (Stephens, 1831)	C	detriti-vorous, parasitic/ predator	Crypto-genic	1875, CZ	AT, BY, BE, BG, HR, CZ, DK, FI, FR, DE, GR, HU, IT-SIC, LV, LT, MT, PL, PT, PT-AZO, PT-MAD, RS, ES, SE, CH, UA, GB	J1, G	stored products, under bark	Borges et al. (2005), Duff (2008), Mendonça and Borges (2009), Santamaria et al. (1996), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptolestes pusilloides (Steel & Howe, 1952)	C	detriti-vorous	Crypto-genic	1978, IT	AT, BE, HR, CZ, DK, FI, FR, DE, GR, HU, IT, IT-SIC, MT, PL, PT, PT-MAD, RS, ES, SE, UA, GB	J	stored products, psychophage/ mills	Duff (2008), Ratti. Coleotteri alieni in Italia., Santamaria et al. (1996)
Cryptolestes pusillus (Schönherr, 1817)	A	detriti-vorous	Tropical, subtropical	1875, CZ	AL, AT, BY, BG, CZ, DK, FR, DE, IT, IT-SAR, MT, PT-AZO	J	synanthropic, grain, damage	Borges et al. (2005), Moncoutier (2002), Santamaria et al. (1996), Šefrova and Lastuvka (2005), Tomov (2009)
Cryptolestes spartii (Curtis, 1834)	C	detriti-vorous	Crypto-genic	1991, FR	AL, EE, FR, FR-COR, DE, PT-AZO, ES, ES-CAN, CH	J1, F	corn flour; dry wood (Saro-thamnus)	Santamaria et al. (1996), Wittenberg et al. (2006)
Cryptolestes turcicus (Grouvelle, 1876)	C	detriti-vorous	Crypto-genic	1904, FR	AL, AT, BE, HR, CZ, DK, FI, FR, DE, GR, HU, IT, IT-SAR, IT-SIC, PL, PT, PT-AZO, PT-MAD, RS, ES, SE, CH, UA, GB	J1	dry fruits, grain, wheat, synanthropic	Borges et al. (2005), Duff (2008), Santamaria et al. (1996), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Languriidae								
Cryptophilus integer (Heer, 1841)	C	detriti-vorous	Crypto-genic	Unknown	AT, MT, PT-AZO, CH	J1	stored products; mycophagous, Vigna	Borges et al. (2005), Mendonça and Borges (2009), Wittenberg et al. (2006)
Cryptophilus obliteratus Reitter,1874	A	detriti-vorous	Asia	1982, DE	AT, DK, FR, DE	I	hay	Callot (2003)
Pharaxonotha kirschii Reitter, 1875	C	detriti-vorous	Crypto-genic	1900, CZ	CZ	J1	psychophage, grain, floour	Šefrova and Lastuvka (2005)
Latridiidae								
Adistemia watsoni (Wollaston, 1871)	C	detriti-vorous	Crypto-genic	1959, CZ	CZ, FR, DE, CH, GB	J1, I	*Tamarindus* seeds, dry fruits, Feeds on fungus, found in herbariium	Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cartodere bifasciata (Reitter, 1877)	A	detriti-vorous	Australasia	2000, DE	AT, BE, CZ, DK, FR, DE, NL, PT-MAD, SE, CH, GB	G, I2	mycophagous, under bark	Bouget and Vincent (2008), Duff (2008), Reemer (2003)
Cartodere delamarei (Dajoz, 1960)	A	detriti-vorous	C & S America	1976, FR	FR	I, J6	mycophagous, vegetal decay	Bouget and Vincent (2008), Vincent (1999)
Cartodere nodifer (Westwood, 1839)	A	detriti-vorous	Australasia	1850, DE	AL, AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, HU, IS, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, LU, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SK, SI, ES, ES-BAL, ES-CAN, SE, CH, UA, GB	I, J6	mycophagous, compost, attic, hay	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Machado and Oromi (2000), Mendonça and Borges (2009), Tomov (2009)
Cartodere constricta (Gyllenhal, 1827)	C	detriti-vorous	Crypto-genic	1889, GB	BY, FR, LV, NO, SE, GB	J1, J6	mycophagous, compost, dry fruits, remains, dust	Bouget and Vincent (2008), Duff (2008), Telnov (1996)
Corticaria elongata(Gyllenhal 1827)	C	detriti-vorous	Crypto-genic	1889, GB	AT, BY, BE, BA, BG, HR, CZ, DK, EE, FI, FR, FR-COR, DE, GR, HU, IT, IT-SAR, IT-SIC, LV, LT, LU, MD, ME, NL, NO, PL, PT, PT-AZO, RO, RS, SK, ES, SE, CH, UA, GB	G, I, J	forest humus, rotten fruits, hay, firewood	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Mendonça and Borges (2009), Moncoutier (2002), Telnov (1996), Tomov (2009)
Corticaria fenestralis Linneaus, 1758)	C	detriti-vorous	Crypto-genic	1908, FR	AT, BY, BG, FR, DE, CH	G, I, J	vegetal refuses, hotels, houses, pine bark	Bouget and Vincent (2008), Duff (2008)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Corticaria fulva (Comolli, 1837)	C	detriti-vorous	Crypto-genic	1874, FR	AT, BY, BG, FR, DE, PT-AZO, CH	I, J6	Fungi on cacao, spices, cereals, decaying plant material	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Corticaria pubescens (Gyllenhal, 1827)	C	detriti-vorous	Crypto-genic	1897, GB	AT, BY, FR, DE, HU, LT, CH	I, J6	tobacco, medicinal plants, on fungus, on decaying plant material	Bouget and Vincent (2008), Freude et al. (1967), Wittenberg et al. (2006)
Corticaria serrata (Paykull 1798)	C	detriti-vorous	Crypto-genic	1997, LT	AT, BY, BG, DE, LT, PT-AZO, CH	I, J1, J6	on fungus, on decaying plant material, corn, barley	Borges et al. (2005), Bouget and Vincent (2008), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Dienerella argus (Reitter, 1884)	C	detriti-vorous	Crypto-genic	1907, GB	FR, LV, GB	G	mycophagous, mosses, old trees	Bouget and Vincent (2008), Duff (2008), Moncoutier (2002), Telnov (1996)
Dienerella costulata (Reitter, 1877)	C	detriti-vorous	Crypto-genic	1900, CZ	CZ, DK, FR	J	foodstuffs, roots, cellars, appartments	Bouget and Vincent (2008), Šefrova and Lastuvka (2005)
Dienerella filum (Aubé, 1850)	C	detriti-vorous	Crypto-genic	1850, FR	AT, BE, BG, CZ, FR, DE, IE, LV, MT, SE, CH, GB	I, J	cereals, herbaria, yeast, on fungus, on decaying plant material	Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Moncoutier (2002), Šefrova and Lastuvka (2005), Tomov (2009)
Lathridius australicus Belon, 1887	A	detriti-vorous	Australasia	Unknown	PT-AZO	U	unknown	Duff (2008), Freude et al. (1967), Mendonça and Borges (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Latridius minutus (Linnaeus, 1767)	C	detritivorous	Cryptogenic	1852, FR	AT, BY, BG, FÖ, FR, FR-COR, DE, LV, LT, PT-AZO, CH, GB	I, J	cereals/ mills, cellars, attic, on fungus, on decaying plant material	Bengtson (1981), Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Enckell et al. (1987), Freude et al. (1967), Moncoutier (2002), Tomov (2009), Wittenberg et al. (2006)
Metophthalmus serripennis Broun 1914	A	detritivorous	Australasia	1928, DE	DE, GB	J	fungi on straw, warehouses; dead leaves	Duff (2008)
Migneauxia orientalis Reitter, 1877	C	detritivorous	Cryptogenic	1993, DE	AT, DK, FR, DE, PL, CH	I, J	rice, on fungus, on decaying plant material	Bouget and Vincent (2008), Wittenberg et al. (2006)
Lyctidae								
Lyctus africanus Lesne, 1907	A	phytophagous	Africa	Unknown	AT, FR, CH	J1	ginger roots; sapwood in field	Freude et al. (1969), Ratti. Coleotteri alieni in Italia., Wittenberg et al. (2006)
Lyctus brunneus (Stephens, 1830)	A	phytophagous	Asia	1850, FR	AL, AT, BY, BG, CZ, DK, FR, DE, GR, IT, IT-SAR, LV, MT, PT, RS, CH	J1	manioc; sapwood	Borges et al. (2005), Freude et al. (1969), Glavendekic et al. (2005), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Lyctus cavicollis J. L. LeConte, 1805	A	phytophagous	North America	1996, DE	AT, FR, DE, CH	J1	wood in houses	Ratti. Coleotteri alieni in Italia., Wittenberg et al. (2006)
Lyctus planicollis J. L. LeConte, 1858	A	phytophagous	North America	1935, FI	AT, FI, FR	J1	*Quercus*, *Fraxinus* (N), wood post in houses	Freude et al. (1969), Ratti. Coleotteri alieni in Italia.)
Lyctus sinensis Lesne, 1911	A	phytophagous	Asia	Unknown	GB	J1	timber yards, rarely in the wild	Duff (2008)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Minthea rugicollis (Walker, 1858)	A	phyto-phagous	Tropical, subtropical	Unknown	IT	J1	timber-feeding beetle; attack wide-pored hardwood, broadleaf or coniferous trees and timber with starch levels of greater than 3% (*Afzelia*, *Artocarpus*, *Avicennia*, *Bombax*, *Helicia*, *Koompassia*, *Shorea*)	Abood and Murphy (2006), Halperin and Geis (1999)
Mordellidae								
Mordellistena cattleyana Champion, 1913	A	phyto-phagous	C & S America	1921, NL	DE, LV, NL	J100	*Cattleya*, *Vandia*, warm greenhouses. On flowers of *Angelica silvestris* in pine forest.	Batten (1976), Lima (1955), Telnov (1996)
Mycetophagidae								
Litargus balteatus Leconte, 1856	A	detriti-vorous	North America	1983, CZ	AT, CZ, FR, IT, PT-AZO, CH	I, J6	on fungus, on decaying plant material, Maize, dried grapes, stored products	Borges et al. (2005), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Typhaea stercorea (Linnaeus, 1758)	C	detriti-vorous	Crypto-genic	1955, BG	AT, BG, FR, DE, IT, IT-SAR, IT-SIC, LT, MT, PT-AZO, CH	I, J, J6	on fungus, on decaying plant material, waste, decay; mills, attic	Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Nitidulidae								
Brachypeplus deyrollei Murray, 1864	A	detriti-vorous	Africa	1999, FR	FR	I	decaying fruits	Ratti. Coleotteri alieni in Italia., Mifsud and Audisio (2008), Moncoutier (2001)
Brachypeplus mauli Gardner & Classey, 1962	A	detriti-vorous	Australasia	2005, PT-AZO	PT-AZO, PT-MAD	J1	stored products; under bark	Audisio (1993), Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)
Carpophilus bifenestratus Murray, 1864	A	phyto-phagous, detriti-vorous	Africa	1993, FR, FR-COR	AL, BA, BG, HR, CY, FR, FR-COR, GR, IT, IT-SAR, IT-SIC, MT, ME, PT-MAD, RS, SI, ES, ES-BAL, ES-CAN	I, J6	rotten fruits	Mifsud and Audisio (2008)
Carpophilus dimidiatus (Fabricius, 1792)	A	phyto-phagous, detriti-vorous	C & S America	1900, CZ	AL, AT, BG, CZ, DK, EE, FR, FR-COR, IT, IT-SAR, IT-SIC, MT, PL, PT-AZO, ES, CH	I, J1	stored products, corn in fields	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008), Moncoutier (2001), Šefrova and Lastuvka (2005), Tomov (2009)
Carpophilus freemani Dobson, 1956	A	phyto-phagous, detriti-vorous	Tropical, subtropical	1976, IT	AL, DK, FR-COR, GR, IT, IT-SAR, IT-SIC, PT-AZO, ES	I, J1	dry fruits, maize in field	Audisio (1993), Borges (1990)
Carpophilus fumatus Boheman, 1851	A	phyto-phagous, detriti-vorous	Africa	1977, IT	AL, IT, IT-SIC, PT, PT-AZO	J1	*Tamarindus* seeds, dry fruits, granaries	Audisio (1993), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia., Vieira et al. (2003)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Carpophilus hemipterus (Linnaeus, 1758)	A	phyto-phagous, detriti-vorous	Asia-Tropical	1800, IT	AL, AT, BY, BG, CZ, FR, FR-COR, DE, IT, IT-SAR, IT-SIC, LT, MT, PL, PT-AZO, ES, CH	I, J1	decaying grapes, dry fruits, cereals in granaries, fruits on ground, mushrooms	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Carpophilus ligneus Murray, 1864	A	phyto-phagous, detriti-vorous	C & S America	1981, ES-CAN	HR, FR, DE, GR, ES-CAN	J1	maize, dry fruits, granaries	Audisio (1993), Machado and Oromi (2000)
Carpophilus marginellus Motschulsky, 1858	A	phyto-phagous, detriti-vorous	Asia-Tropical	1938, GB	AT, BY, BE, BG, CZ, DK, FI, FR, FR-COR, DE, GR, IT, IT-SAR, IT-SIC, MT, NL, NO, PL, PT-AZO, PT-MAD, ES, ES-CAN, SE, CH, GB	J1	mainly domestic; cereals, compost, saprophagous	Audisio (1993), Borges et al. (2005), Duff (2008), Machado and Oromi (2000), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Reemer (2003), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Carpophilus mutilatus Erichson, 1843	A	phyto-phagous, detriti-vorous	C & S America	1900, CZ	AT, BG, CZ, DK, FR, FR-COR, IT, IT-SAR, IT-SIC, LT, MT, PT-AZO	J1, I	dry fruits	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008), Šefrova and Lastuvka (2005), Tomov (2009)
Carpophilus nepos Murray, 1864	A	phyto-phagous, detriti-vorous	Tropical, subtropical	Unknown	AL, BA, BG, HR, CY, FR, FR-COR, GR, GR-CRE, GR-ION, GR-NEG, GR-SEG, IT-SAR, IT-SIC, MT, PT, PT-AZO, RO, RU, SI, ES, ES-BAL, ES-CAN, UA	J1, I	dry fruits, outdoors in medi-terranean; houses in central europe	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Mifsud and Audisio (2008), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Carpophilus obsoletus Erichson, 1843	A	phyto-phagous, detriti-vorous	Asia-Tropical	1895, GR-CRE	CY, CZ, DK, FR, FR-COR, GR, GR-CRE, IT, IT-SAR, IT-SIC, MT, PT, ES,	J1, I	rotten fruits outdoors, granaries (maize, corn)	Audisio (1993), Mifsud and Audisio (2008), Šefrova and Lastuvka (2005)
Carpophilus pilosellus Motschulsky, 1858	A	phyto-phagous, detriti-vorous	Asia-Tropical	1983, CZ	AT, HR, CZ, FR, IT, IT-SAR, IT-SIC, PT-AZO, RS, SI	J1, I	dry fruits, fruits on ground, poultry dung	Audisio (1993)
Carpophilus succisus Erichson, 1843	A	phyto-phagous, detriti-vorous	C & S America	2005, PT-AZO	PT-AZO	J1	maize	Borges et al. (2005)
Carpophilus zeaphilus Dobson, 1969	A	phyto-phagous, detriti-vorous	Africa	1985, PT, ES	AL, FR, IT, IT-SIC, PT, ES	J1, I	maize	Audisio (1993), Ratti. Coleotteri alieni in Italia.)
Epuraea luteola Erichson, 1843	A	detriti-vorous	C & S America	1970, ES-CAN, PT-MAD	AL, FR, IT, IT-SAR, IT-SIC, MT, MD, PT-MAD, ES-CAN	G, I	fruits (*Prunus*), mushrooms	Audisio (1993), Machado and Oromi (2000), Mifsud and Audisio (2008), Ratti. Coleotteri alieni in Italia., Tomov (2009)
Epuraea ocularis Fairmaire, 1849	A	detriti-vorous	Asia-Tropical	1900, IT	AL, AT, FR, DE, IT, IT-SIC, MD, ES, ES-CAN, CH	J	mycophagous; manioc, dry fruits	Machado and Oromi (2000), Mifsud and Audisio (2008), Ratti. Coleotteri alieni in Italia.)
Glischrochilus fasciatus (Olivier, 1790)	A	phyto-phagous, parasitic/ predator	North America	1977, DE	DE, CH	I	bark beetle predator, vegetables, fruits	Audisio (1993)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Glischrochilus quadrisignatus (Say, 1835)	A	phyto-phagous, parasitic/ predator	North America	1950, DE	AL, AT, BY, BA, BG, HR, CZ, FR, DE, GR, HU, IT, LI, LT, MD, ME, PL, RO, RU, RS, SK, SI, SE, CH, UA, GB	I	bark beetle predator, vegetables, fruits	Audisio (1993), Glavendekic et al. (2005), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia., Reemer (2003), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Meligethes ruficornis (Marsham, 1802)	C	phyto-phagous	Crypto-genic	Unknown	MT, GB	G,I2	*Ballota nigra* pollen	Audisio (1993), Duff (2008), Mifsud and Audisio (2008)
Nitidula carnaria (Schaller, 1783)	C	detriti-vorous	Crypto-genic	2005, PT-AZO	MT, PT-AZO	J1		Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008)
Omosita colon (Linnaeus, 1758)	C	detriti-vorous	Crypto-genic	2005, PT-AZO	PT-AZO	E, G, I, J	old bones left on the soil surface	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009)
Omosita discoidea (Fabricius, 1775)	C	detriti-vorous	Crypto-genic	2005, PT-AZO	PT-AZO	E, G, I, J	cadavers, carrion	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009)
Phenolia tibialis (Boheman, 1851)	A	detriti-vorous	Africa	2005, PT-AZO	PT-AZO	I2	decaying and rotting fruits	Borges et al. (2005), Mendonça and Borges (2009)
Stelidota geminata (Say, 1825)	A	phyto-phagous, parasitic/ predator	C & S America	1900, IT	FR, IT, PT-AZO, SI, ES-CAN, CH	I	in insect galleries under oak bark, strawberries and other fruits	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia.)
Urophorus humeralis (Fabricius, 1798)	A	detriti-vorous	Asia-Tropical	1976, IT	AL, AT, BA, BG, HR, CY, FR, FR-COR, GR, GR-CRE, GR-ION, GR-NEG, GR-SEG, IT, IT-SAR, IT-SIC, MT, ME, PT, PT-MAD, RU, RS, SI, ES, ES-BAL, ES-CAN, UA	J1	dry fruits and vegetables	Audisio (1993), Machado and Oromi (2000), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Passandridae								
Catogenus rufus (Fabricius, 1798)	A	parasitic/ predator	North America	2007, AT	AT	F9	predator of wood-boring Coleoptera in riverine forest	Mitter and Schuh (2008)
Phalacridae								
Phalacrus politus Melsheimer, 1844	A	phyto-phagous	North America	Unknown	PT-AZO	I	sweetcorn	Borges et al. (2005), Mendonça and Borges (2009)
Ptiliidae								
Acrotrichis henrici (Matthews, 1872)	A	detriti-vorous	North America	1966, GB	DK, DE, NL, NO, SE, GB	G, J6	compost	Duff (2008), Freude et al. (1971), Reemer (2003), Sörensson and Johnson (2004)
Acrotrichis insularis (Maklin, 1852)	A	detriti-vorous	North America	1965, NO, BG	AT, CZ, DK, FI, FR, DE, IE, NL, NO, PT-AZO, PT-MAD, SE, CH, GB	G, J6	compost, saprophagous, fungivore	Borges et al. (2005), Duff (2008), Freude et al. (1971), Freude et al. (1989), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Sörensson and Johnson (2004), Wittenberg et al. (2006)
Acrotrichis josephi (Matthews, 1872)	A	detriti-vorous	North America	1987, GB	GB	I	grass moving; litter, roting organic material	Duff (2008), Sörensson and Johnson (2004)
Acrotrichis sanctaehelenae Johnson, 1972	A	detriti-vorous	Africa	1964, ES-CAN	FR, IT, PT, ES-CAN, CH, GB	I, J6	anthropogenic habitats, dung, compost, rotting organic substances	Duff (2008), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia., Sörensson and Johnson (2004), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Baeocrara japonica (Matthews, 1884)	A	detriti-vorous	Asia	1974, FI	AT, BY, CZ, DK, FI, DE, HU, LV, NO, SK, SE	I, J	compost, saprophagous, fungivore	Freude et al. (1989), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Sörensson and Johnson (2004)
Ptinella cavelli (Broun, 1893)	A	detriti-vorous	Australasia	1936, GB	IE, GB	G3, G4	under tight bark of dead broad-leaves and conifers	Sörensson and Johnson (2004)
Ptinella errabunda Johnson, 1975	A	detriti-vorous	Australasia	1925, GB	DE, IE, NL, GB	G3	under tight bark of most species of dead trees	Freude et al. (1989), Reemer (2003), Sörensson and Johnson (2004)
Ptinella simsoni (Matthews, 1878)	A	detriti-vorous	Australasia	1929, GB	GB	G,I2 ?	heap in crass cuttings in wooded areas around large coastal cities (e.g. London, Liverpool)	Sörensson and Johnson (2004)
Ptinella taylorae Johnson, 1977	A	detriti-vorous	Australasia	1967, GB	IE, GB	G3, G4	under tight bark of dead trees	Duff (2008), Sörensson and Johnson (2004)
Bambara contorta (Dybas, 1066)	A	detriti-vorous	Tropical, subtropical	1997, DE	DE	E5	forest litter	Ryndevich (2004)
Bambara fusca (Dybas, 1966)	A	detriti-vorous	North America	1997, DE	DE	E5	forest litter	Sörensson and Johnson (2004)
Ptinella johnsoni Rutanen, 1985	A	detriti-vorous	Asia	1978, FI, SE	FI, NO, SE	E5	taiga, litter	Sörensson and Johnson (2004)
Ptilodactylidae								
Ptilodactyla exotica Chapin, 1927	A	detriti-vorous	Africa	1971, IT	FR, IT, SI, CH	J1, J100	*Dracaena* in greenhouse; plants in appartments	Aberlenc and Allemand (1997), Mann (2006), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ptilodactyla luteipes Pic, 1924	C	detriti-vorous	Crypto-genic	1952, DE	DE	J100	greenhouse	
Ripiphoridae								
Ripidius pectinicornis Thunberg, 1806	A	parasitic/ predator	Asia	Unknown	DK, FI, IT, NL	J	*blatta* parasitoid, synanthropic	Bétis (1912), Falin (2001), Freude et al. (1969)
Rutelidae								
Popilia japonica Newman, 1841	A	phyto-phagous	Asia	2005, PT-AZO	PT-AZO	I2	polyphagous deciduous	Borges et al. (2005), Mendonça and Borges (2009), Paulian and Baraud (1982)
Salpingidae								
Aglenus brunneus (Gyllenhall)	C	detriti-vorous	Crypto-genic	2005, PT-AZO	PT-AZO	J1	anthropophilic: attic, stables, poultry, damage cultivated mushrooms; rodent nests in forests	Borges et al. (2005)
Silvanidae								
Ahasverus advena (Waltl, 1832)	A	detriti-vorous	C & S America	1875, CZ	AT, BY, BG, CZ, DK, EE, FI, DE, LT, MT, PL, PT-AZO, SE, CH	I, J1	saprophagous-stored products; compost, clethrophage in field	Borges et al. (2005), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Cryptamorpha desjardinsi (Guérin-Méneville, 1844)	A	detriti-vorous, parasitic/ predator	Tropical, subtropical	1911, DE	BE, DK, DE, NL, PT-AZO, ES-CAN	G, I, J	banana, ananas; dead plants, bark, cadavers; larva predator	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Ratti (2007)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Nausibius clavicornis (Kugelann, 1794)	C	detriti-vorous	Crypto-genic	1906, FR	DK, FR, PT-AZO	J1	stored products	Borges et al. (2005), Mendonça and Borges (2009), Ratti (2007), Moncoutier (2002)
Oryzaephilus acuminatus Halstead, 1980	A	detriti-vorous	Asia	1980, GB	GB	J1	coconut, *azadirachta* seeds	Duff (2008)
Oryzaephilus mercator (Fauvel, 1889)	A	detriti-vorous	Tropical, subtropical	1962, CZ	AT, BY, BG, CZ, DK, EE, HU, LV, MT, NO, PT, PT-AZO, ES-CAN, CH	J1	psychophage, stored products	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Oryzaephilus surinamensis (Linnaeus, 1758)	C	detriti-vorous	Crypto-genic	1894, PT	AT, BY, BG, CZ, DK, EE, FR, DE, HU, LV, LT, MT, NO, PT, PT-AZO, RS, ES-CAN, CH	J1	psychophage, stored products	Borges et al. (2005), Glavendekic et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Silvanus lateritius (Broun, 1880)	A	detriti-vorous	Australasia	Unknown	PT-AZO	J1		Borges et al. (2005), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia.)
Silvanus lewisi Reitter, 1876	A	detriti-vorous	Asia	Unknown	MT	J1, G	rice, manioc, stored products; under bark of dead trees in field	Ratti (2007), Ratti. Coleotteri alieni in Italia.)
Silvanus recticollis Reitter, 1876	A	detriti-vorous	Africa	Unknown	IT-SAR, IT-SIC	J1		Ratti. Coleotteri alieni in Italia.)
Staphylinidae								
Acrotona pseudotenera (Cameron, 1933)	A	parasitic/ predator	Asia	1988, FI	AT, DK, FI, DE, NO, SE, CH	I	compost, predator, fungivorous	Luka et al. (2009), Ødegaard and Tømmerås (2000), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Adota maritima Mannerheim, 1843	A	parasitic/ predator	North America	Unknown	GB	B	decomposing seaweed, predator flies	Duff (2008)
Aleochara puberula Klug, 1833	C	parasitic/ predator	Crypto- genic	Unknown	AT, PT-AZO	I1, J	predator of cyclorrhaphous Diptera (*Musca*) in stables	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Anotylus nitidifrons (Wollaston, 1871)	C	parasitic/ predator	Crypto- genic	Unknown	PT-AZO, ES-CAN	I	predator on *Delia* (carrots)	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta dilutipennis (Motschulsky, 1858)	A	parasitic/ predator	Africa, Asia	1995, IT	AL, IT, PT-AZO, ES-CAN	U		Borges (1990), Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta mucronata (Kraatz, 1859)	A	parasitic/ predator	Tropical, subtropical	2002, ES	IT, ES	I2	decaying vegetals, citrus groves	Gamarra and Outerelo (2005), Monzo et al. (2005)
Bisnius palmi (Smetana, 1955)	A	parasitic/ predator	North America	Unknown	AL, CZ, IT, IT-SIC	I, J6		Newton. Staphylinini Species Catalog Draft)
Bisnius parcus (Sharp, 1874)	A	parasitic/ predator	Asia- Temperate	1950, FI, DE	AL, AT, DK, FI, FR, DE, IT, NO, ES-CAN, SE, CH, GB	I, J6	compost, predator	Cho (2008), Duff (2008), Korge (2005), Luka et al. (2009), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Tronquet (2006)
Bohemiellina flavipennis (Cameron, 1921)	C	parasitic/ predator	Crypto- genic	1941, FI, DE	AT, BE, DK, FI, FR, DE, NO, SE, GB	B1, E3	compost	Ødegaard and Tømmerås (2000), Tronquet (2006)
Carpelimus bilineatus Stephens, 1834	C	phyto- phagous	Crypto- genic	2005, PT-AZO	PT-AZO	B1, E3	grassy coastal patches, sand dunes	Borges et al. (2005), Mendonça and Borges (2009), Tronquet (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Carpelimus corticinus (Gravenhorst, 1806)	C	phyto-phagous	Crypto-genic	2005, PT-AZO	PT-AZO	B1, E3	floodplains, river banks, sand beaches	Borges (1990), Borges et al. (2005), Tronquet (2006)
Carpelimus gracilis (Mannerheim, 1830)	C	parasitic/ predator	Crypto-genic	2005, PT-AZO	PT-AZO	B1, E3	floodplains, river banks, sand beaches	Borges et al. (2005), Tronquet (2006)
Carpelimus pusillus (Gravenhorst, 1802)	C	parasitic/ predator	Crypto-genic	2005, PT-AZO	PT-AZO	B1, E3	floodplains, river banks, sand beaches	Borges et al. (2005), Mendonça and Borges (2009)
Carpelimus subtilis (Erichson, 1839)	C	unknown	Crypto-genic	2005, PT-AZO	PT-AZO	B	floodplains, river banks, sand beaches	Borges et al. (2005), Duff (2008), Vorst et al. (2007)
Carpelimus zealandicus (Sharp, 1900)	A	unknown	Australasia	2000, DE	AT, BE, DE, SE, CH, GB	E	Sandy banks	Cuppen (2003), Korge (2005), Luka et al. (2009)
Cilea silphoides (Linnaeus, 1767)	C	parasitic/ predator	Crypto-genic	2005	PT-AZO, ES-CAN	U	cattle dung	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Tronquet (2006)
Coproporus pulchellus (Erichson, 1839)	A	unknown	North America	Unknown	PT-AZO, PT-MAD, ES-CAN	U		Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Diestota guadalupensis Pace, 1987	A	unknown	C & S America	1982, IT	IT	U		Ratti. Coleotteri alieni in Italia.)
Leptoplectus remyi (Jeannel, 1961)	A	parasitic/ predator	Asia	Unknown	CH	U		Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Lithocharis nigriceps (Kraatz, 1859)	A	parasitic/ predator	Asia-Tropical	1912, CZ	AL, AT, BE, CZ, DK, EE, FI, FR, DE, HU, IT, LV, NL, NO, PL, PT-AZO, SK, ES, SE, CH, UA, GB	I, J6	compost, predator.	Borges et al. (2005), Duff (2008), Freude et al. (1964), Korge (2005), Luka et al. (2009), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Tronquet (2006)
Myrmecocephalus concinna (Erichson,1840)	C	detriti-vorous	Crypto-genic	1970, DE	DE, PT-AZO, PT-MAD, RU, ES-CAN, SE, GB	G	deadwood	Duff (2008), Korge (2005), Machado and Oromi (2000), Tronquet (2006)
Myrmecopora brevipes Butler, 1909	C	parasitic/ predator	Crypto-genic	Unknown	FR, IE, GB	U	in wet sand under plants	Anderson (1997), Scheerpeltz (1972)
Nacaeus impressicollis (Motschulsky, 1857)	A	unknown	Africa (or Asia?)	2005, PT-AZO	CZ, PT-AZO	I2,G?		Borges et al. (2005), Mendonça and Borges (2009), Rogé (2003), Tronquet (2006)
Oligota parva Kraatz, 1862	A	detriti-vorous	C & S America	1858, FR	AT, BE, BA, HR, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, IT, IT-SIC, NL, NO, PL, PT-AZO, PT-MAD, ES-CAN, SE, CH, GB	I, J6	compost, predator, fungivorous. Synanthropic	Borges et al. (2005), Freude et al. (1974), Korge (2005), Luka et al. (2009), Machado and Oromi (2000), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Reemer (2003), Wittenberg et al. (2006)
Oxytelus migrator Fauvel, 1904	A	detriti-vorous	Asia	1975, DK	AT, BE, CZ, DK, FR, DE, IT, LT, LU, NO, SE, CH	I, J6	compost, saprophagous	Korge (2005), Luka et al. (2009), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Paraphloeostiba gayndahensis (Mac Leay, 1871)	A	detriti-vorous	Australasia	1988, IT	FR, DE, IT, IT-SIC, PT, ES, ES-CAN, CH	I, J6	rotting fallen fruits of various trees, decaying vegetals	Duff (2008), Korge (2005), Luka et al. (2009), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia., Tronquet (2006), Wittenberg et al. (2006)
Philonthus rectangulus Sharp, 1874	A	parasitic/ predator	Asia-temperate	1920, IT	AL, AT, BE, BA, BG, HR, CZ, DK, EE, FI, FR, DE, GR, HU, IT, IT-SAR, LV, LT, LU, MD, ME, NL, NO, PT, PT-AZO, PT-MAD, RO, RS, SK, SI, ES, ES-CAN, SE, CH, UA, GB	I, J6	compost, predator	Borges et al. (2005), Coiffait (1972), Korge (2005), Luka et al. (2009), Machado and Oromi (2000), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Tomov (2009), Tronquet (2006), Wittenberg et al. (2006)
Philonthus spinipes Sharp, 1874	A	parasitic/ predator, detrivorous	Asia	1980, IT	AL, AT, BG, CZ, DK, FR, IT, LT, RU, CH	J1, J6	in stable litter, cadavers	Callot (1993), Luka et al. (2009), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Tomov (2009), Tronquet (2006)
Tachinus sibiricus Sharp, 1888	A	unknown	Asia	Unknown	AT	U		
Trichiusa immigrata Lohse, 1984	A	unknown	North America	1975, DE	AL, AT, BE, CZ, DK, FR, DE, IT, NO, ES-CAN, SE, CH	I, I2	compost, predator, fungivorous	Korge (2005), Luka et al. (2009), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Tronquet (2006), Wittenberg et al. (2006)
Teropalpus unicolor (Sharp, 1900)	A	parasitic/ predator, detrivorous	Australasia	Unknown	GB	I2	halophilous	Duff (2008), Kuschel (1990)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Tenebrionidae								
Alphitobius diaperinus (Panzer, 1797)	A	parasitic/ predator, detrivorous	Tropical, subtropical	1921, ME	AT, BG, DK, EE, FR, FR-COR, DE, HU, IT, LV, LT, MT, ME, NO, ES-CAN, CH, GB	J1, J6, G	minor pest of residues, common inhabitant of chicken houses; feeds on faeces and wastes; outdoors in rotten trunks and bird/ bat nests	Borges et al. (2005), Duff (2008), Freude et al. (1969), Tomov (2009), Wittenberg et al. (2006)
Alphitobius laevigatus (Fabricius, 1781)	A	detriti-vorous	Tropical, subtropical	Unknown	DK, EE, FR, MT, ES-CAN, GB	J1, J6, G	minor pest of residues; stored products; outdoors on fungi in trunks	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000)
Alphitophagus bifasciatus (Say, 1823)	C	detriti-vorous	Crypto-genic	1940, BG	AL, AT, BG, HR, DK, FI, FR, DE, GR, HU, LT, NO, RO, SE, CH	J1, J6, G	minor pest of residues; compost, Mainly domestic in rotten fruits; under bark old stumps	Freude et al. (1969), Ødegaard and Tømmerås (2000), Tomov (2009), Wittenberg et al. (2006)
Cynaeus angustus (Leconte, 1851)	A	detriti-vorous	C & S America	1988, SE	FI, FR, DE, SE	J6	saprophagous, waste heaps	Ferrer (2004), Ferrer and Andersson (2002), Reibnitz and Schawaller (2006), Soldati (2007)
Cynaeus depressus Horn, 1870	A	detriti-vorous	C & S America	1988, SE	SE	U	waste heaps	Ferrer (2004), Mannerkoski and Ferrer (1992)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Gnathocerus cornutus (Fabricius, 1798)	A	detriti-vorous	C & S America	1900, CZ	AT, CZ, EE, FR, DE, IT, IT-SAR, IT-SIC, LV, MT, PT-AZO, ES-CAN, CH, GB	J1	cereal grains in warehouses	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Gnathocerus maxillosus (Fabricius, 1801)	C	detriti-vorous	Crypto-genic	1977, IT	AL, FR, FR-COR, IT, ES-CAN	J1	cereal grains in warehouses	Machado and Oromi (2000), Tomov (2009)
Latheticus oryzae Waterhouse, 1880	A	detriti-vorous	Asia	1973, BG, CZ	AL, AT, BG, CZ, DK, EE, FR, IT, IT-SIC, RS, ES-CAN, CH, GB	J1	stored products, cereals in warehouses	Duff (2008), Freude et al. (1969), Glavendekic et al. (2005), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Lyphia tetraphylla (Fairmaire, 1856)	A	detriti-vorous	Asia	1934, CZ	HR, CZ, FR, GR, ME	U		Šefrova and Lastuvka (2005)
Palorus ratzeburgi (Wissmann, 1848)	A	detriti-vorous	Africa	1976, LT	HR, DK, FR, GR, LT, ES-CAN, GB	J1	stored products, mainly cereals; mycophagous	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000)
Palorus subdepressus (Wollaston, 1864)	A	detriti-vorous	Africa	1975, BG	BG, HR, CZ, DK, FR, GR, MT, PT-AZO, ES-CAN, GB	J1	stored products, mainly cereals; mycophagous	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Tomov (2009)
Tribolium castaneum (Herbst, 1797)	C	detriti-vorous	Crypto-genic	1900, CZ	AL, AT, BG, CZ, DK, EE, FR, FR-COR, DE, GR, HU, LV, LT, MT, ME, NO, PT, PT-AZO, RO, ES-CAN, CH, GB	J1, J2	stored products	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Tribolium confusum Jacquelin du Val, 1868	A	detriti-vorous	Africa	1900, CZ	AL, AT, BG, HR, CZ, DK, EE, FR, DE, GR, HU, IT, LV, LT, NO, PT-AZO, ES-CAN, CH, GB	J1, J2	stored products	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Tribolium destructor Uyttenboogaart, 1933	A	detriti-vorous	tropical	1927, DE	AL, AT, BG, CZ, DK, EE, DE, HU, IT, LV, LT, NO, ES-CAN, CH, GB	J1, J2	stored products	Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Zophobas morio (Fabricius, 1776)	A	detriti-vorous	C & S America	Unknown	LV	J	used as food for reptile pets	Thomas (1995)
Trogidae								
Omorgus subcarinatus (MacLeay, 1864)	A	detriti-vorous	Australasia	1997, ES	ES	J1, J6		Bercedo (1997)
Omorgus suberosus (Fabricius, 1775)	A	detriti-vorous	Australasia	1997, ES	ES	J1, J6		Bercedo (1997)
Trogossitidae								
Lophocateres pusillus (Klug, 1832)	A	detriti-vorous	Asia	1962, CZ	AL, CZ, DK, IT	J1	psychophage, necrophagous; rice, stored products	Šefrova and Lastuvka (2005)
Tenebroides maroccanus Reitter 1884	A	parasitic/ predator	Africa	2005, PT-AZO	PT-AZO	G	predator egg *Lymantria dispar*	Borges et al. (2005)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Tenebroides mauritanicus (Linnaeus, 1758)	A	detritivorous	Africa	1803, PT	AT, BG, CZ, DK, EE, DE, IT, LV, LT, PT, PT-AZO, RS, CH	J1, G	psychophage, carnivorous; stored products, bark in field	Borges et al. (2005), Glavendekic et al. (2005), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009)
Zopheridae								
Microprius rufulus (Motschulsky, 1863)	A	unknown	Africa	Unknown	MT	U	timber	Schuh and Mifsud (2000)
Pycnomerus fuliginosus Erichson, 1842	A	unknown	Australasia	1962, GB	GB	B2, I2		Duff (2008)
Pycnomerus inexpectus (Jaquelin Du Val, 1859)	C	unknown	Cryptogenic	1901, IT	AL, AT, BE, CZ, FR, IT, ES, GB	J100	orchid greenhouses	Ratti. Coleotteri alieni in Italia.)

Table 9.5.2. List and characteristics of the Coleoptera species alien *in* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Anobiidae							
Anobium punctatum De Geer, 1774	phyto-phagous	Europe	Unknown	PT-AZO, ES-CAN	J	wooden furnitures; twigs	Borges et al. (2005), Espanol (1992), Machado and Oromi (2000), Mendonça and Borges (2009)
Oligomerus ptilinoides (Wollaston, 1854)	phyto-phagous	Medi-terranean region	Unknown	AT, DE, HU, PL, PT-MAD, SK, ES-CAN, CH	G, J1	wood broadleaved trees and furnitures	De Laclos and Büche (2009), Espanol (1992), Machado and Oromi (2000), Wittenberg et al. (2006)
Ptinus dubius Sturm, 1837	detriti-vorous	Europe	Unknown	ES-CAN	J1	stored products	Machado and Oromi (2000)
Sphaericus gibboides (Boieldieu, 1854)	detriti-vorous	Medi-teranean	Unknown	DK, GB	J	psychophage; dry roots	Duff (2008)
Anthicidae							
Cordicomus instabilis (Schmidt, 1842)	unknown	Palaearctic	Unknown	PT-AZO	B1	sandy grounds	Borges et al. (2005)
Cyclodinus humilis (Germar, 1824)	unknown	Europe	Unknown	PT-AZO	U	clayey ground	Borges et al. (2005), Mendonça and Borges (2009)
Omonadus formicarius (Goeze, 1777)	detriti-vorous	Europe, cosmopolitan almost	Unknown	PT-AZO	J6	vegetal decay	Borges et al. (2005), Mendonça and Borges (2009)
Aphodiidae							
Calamosternus granarius (Linnaeus, 1767)	detriti-vorous	North Africa, Europe	Unknown	PT-AZO	E	dung	Borges et al. (2005), Mendonça and Borges (2009)
Pleurophorus caesus (Creutzer, 1796)	detriti-vorous	Eurasia, north America	Unknown	PT-AZO	E	dung	Borges et al. (2005), Mendonça and Borges (2009)
Buprestidae							
Agrilus angustulus (Illiger, 1803)	phyto-phagous	Europe	2005, PT-AZO	PT-AZO	G	*Quercus*	Borges et al. (2005), Cobos (1986), Freude et al. (1979), Schaefer (1949), Théry (1942)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Buprestis novemmaculata Linnaeus, 1758	phyto-phagous	All over Europe	2005, PT-AZO	PT-AZO	I2	conifers	Borges et al. (2005), Cobos (1986), Freude et al. (1979), Mendonça and Borges (2009), Schaefer (1949), Théry (1942)
Melanophila acuminata (De Geer, 1774)	phyto-phagous	holarctic	Unknown	GB	F4	conifers	Cobos (1986), Duff (2008), Freude et al. (1979), Schaefer (1949), Théry (1942)
Byrrhidae							
Simplocaria semistriata (Fabricius, 1794)	phyto-phagous	Central & southeast Europe	Unknown	FÖ	E	synathropic steppe; feeds on moss (*Mnium*)	Bengtson (1981), Enckell et al. (1987), Freude et al. (1979)
Carabidae							
Abax parallelus Duftschmid, 1812	parasitic/ predator	Central Europe	1800, GB	GB	G		Duff (2008), Jeannel (1942), Luff (2007), Valemberg (1997)
Amara aenea (De Geer, 1774)	phyto-phagous	Palaearctic	Unknown	PT-AZO, ES-CAN	E, I	Poaceae seeds	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Valemberg (1997)
Amara anthobia A. Villa & G.B. Villa, 1833	phyto-phagous	Medi-terranean region, Central Europe	Unknown	GB	F4, B1	Poaceae seeds; sandy soils	Duff (2008), Luff (1998), Luff (2007)
Amara aulicus (Panzer, 1797)	phyto-phagous	Palaearctic	Unknown	FÖ	E, I	compositea & carduaceae seeds, waste lands	Bengtson (1981), Enckell et al. (1987)
Amara montivaga Sturm, 1825	phyto-phagous	Central Europe, mountains	1972, IE	IE	F4, B1, I	Poaceae seeds	Anderson et al. (2000)
Anisodactylus binotatus (Fabricius, 1787)	parasitic/ predator	Medi-terranean region, Central Europe	Unknown	IS, IE, LI, PT-AZO, PT-MAD, GB	E3, I	Apiaceae seeds	Anderson et al. (2000), Duff (2008), Borges et al. (2005), Luff (2007), Mendonça and Borges (2009), Valemberg (1997)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Callistus lunatus (Fabricius, 1775)	parasitic/ predator	Europe, Asia minor	Unknown	GB	B1, F9, G	sandy soil, under felled trunks, bark, tree bases	Duff (2008), Luff (1998), Luff (2007)
Carabus auratus Linnaeus, 1758	parasitic/ predator	Western Europe	Unknown	GB	I1,E, G5	plains, waste lands, predator molluscs	Duff (2008), Luff (2007), Turin et al. (2003)
Carabus cancellatus Linnaeus, 1758	parasitic/ predator	Western and Central Europe	Unknown	GB	E5	dry soil, field, forest edge	Duff (2008), Luff (2007), Turin et al. (2003)
Carabus convexus Fabricius, 1775	parasitic/ predator	Eurosiberian	1836, GB	GB	G	forests	Duff (2008), Luff (2007), Turin et al. (2003)
Carabus nemoralis O.F. Müller, 1764	parasitic/ predator	West Palaearctic	Unknown	IS	I2, I1, G	woodlands, fields, gardens	Libungan et al. (2008), Turin et al. (2003)
Demetrias atricapillus (Linnaeus, 1758)	parasitic/ predator	Eurosiberian	Unknown	ES-CAN	F9, D	in vegetal decays along rivers and bogs, *Carex*, *Oenanthe*	Machado and Oromi (2000)
Epaphius secalis (Paykull, 1790)	parasitic/ predator	Eurosiberian	Unknown	IS	F9	along rivers, mountains (orophilous)	
Graniger femoralis (Coquerel, 1858)	phyto-phagous	Spain, Italy, Crimea	Unknown	ES-CAN	H	seeds, under stones	Machado and Oromi (2000)
Harpalus distinguendus (Duftschmid, 1812)	phyto-phagous	Medi-terranean	Unknown	ES-CAN	I	seeds; dry soils, paths, fields, dunes	Machado and Oromi (2000), Mendonça and Borges (2009)
Leistus rufomarginatus (Duftschmid, 1812)	parasitic/ predator	Eastern, central, western Europe	1942, GB	GB	G, I	mountains, forests, waste lands	Duff (2008), Luff (1998), Luff (2007)
Leistus terminatus (Panzer, 1793)	parasitic/ predator	Eurosiberian	Unknown	IS	F9, G	osieries	
Licinus punctatulus (Fabricius, 1792)	parasitic/ predator	Spain, North Africa	Unknown	PT-AZO, ES-CAN	H5	under stones, arid, sandy environments	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Valemberg (1997)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Lymnastis galilaeus Piochard de la Brûlerie, 1876	parasitic/ predator	Southern Europe	Unknown	AT, HU, UA	B, D	waste, near littoral, bogs	Valemberg (1997)
Microlestes minutulus (Goeze, 1777)	parasitic/ predator	Palaearctic	1976, GB	GB	G1	dry soil, under deciduous	Duff (2008), Luff (1998), Luff (2007)
Notaphus varius (Olivier, 1795)	parasitic/ predator	Europe, Minor Asia	Unknown	ES-CAN	D6, F9	salty marshes, along rivers, lakes	Machado and Oromi (2000), Ortuno and Toribio (2005)
Ocydromus tetracolus (Say, 1823)	parasitic/ predator	Palaearctic	Unknown	IS	F9	humid environments, herbs, along rivers	
Paranchus albipes (Fabricius, 1796)	parasitic/ predator	Europe, North Africa	Unknown	PT-AZO	F9, B	along rivers, coast	Borges et al. (2005), Mendonça and Borges (2009)
Philochthus guttula (Fabricius, 1792)	parasitic/ predator	Europe, Asia minor	1900, IE	IE	G, D	near bogs in forests	Anderson et al. (2000)
Pterostichus angustatus (Duftschmid, 1812)	parasitic/ predator	Northern and Central Europe	1900, GB	GB	H, G	associated with burnt sites	Duff (2008), Luff (1998), Luff (2007)
Pterostichus cristatus (Dufour, 1820)	parasitic/ predator	Europe	1800, GB	GB	G, F9	under stones in fresh, humid woods	Duff (2008), Luff (1998), Luff (2007)
Pterostichus vernalis (Panzer, 1796)	parasitic/ predator	Europe	Unknown	PT-AZO	E3	waste in wet grasslands, near bogs	Borges et al. (2005), Duff (2008), Mendonça and Borges (2009)
Scybalicus oblongiusculus (Dejean, 1829)	parasitic/ predator	Europe	1879, GB	GB	E2, I	in colonies in non-cultivated fields	Duff (2008), Luff (1998), Luff (2007)
Sphodrus leucophthalmus (Linnaeus, 1758)	parasitic/ predator	West Palaearctic	Unknown	IE, ES-CAN, GB	J2	cellars, stables	Anderson et al. (2000), Duff (2008), Machado and Oromi (2000), Luff (1998), Luff (2007), Valemberg (1997)
Tachyta nana (Gyllenhal, 1810)	parasitic/ predator	Holarctic	Unknown	ES-CAN	G3	under humid bark, in bark beetle galleries in *Abies* and *Cedrus*	Machado and Oromi (2000)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trechus subnotatus Dejean, 1831	parasitic/ predator		1940, IE	IE, GB	J6, J2, I2	near littoral; in compost in Ireland	Duff (2008), Anderson et al. (2000), Luff (1998), Luff (2007)
Tschitscherinellus cordatus (Dejean, 1825)	phyto-phagous	Spain, North Africa, Crimea	Unknown	ES-CAN	H5	mountains under stones, arid, sandy environments; granivore	Machado and Oromi (2000)
Clambidae							
Clambus pallidulus Reitter, 1911	detriti-vorous	southern Europe, Minor Asia	Unknown	AL, DK, DE, HU, IE, NL, SE, CH, GB	G	in hollow *Malus*, debris in rotten stump, in moss among rotten logs	Duff (2008)
Cleridae							
Enoplium serraticorne (Olivier, 1790)	parasitic/ predator	Medi-terranean Region	1990, CZ	CZ	J6	predatory	Freude et al. (1979), Šefrova and Lastuvka (2005)
Opilo domesticus (Sturm, 1837)	parasitic/ predator	Europe, North Africa	Unknown	PT-AZO	J	buildings, prey anobiids	Borges et al. (2005), Freude et al. (1979)
Opilo mollis (Linnaeus, 1758)	parasitic/ predator	Europe, North Africa	Unknown	PT-AZO	J	timber, prey larvae anobiids, buildings	Borges et al. (2005), Freude et al. (1979)
Corylophidae							
Sericoderus lateralis (Gyllenhal, 1827)	detriti-vorous	palaearctic	Unknown	PT-AZO	I, J1	moldy plant remains in warm places, especially garden compost and grass cuttings	Borges et al. (2005), Bowestead (1999), Mendonça and Borges (2009)
Cryptophagidae							
Atomaria apicalis Erichson, 1846	detriti-vorous	Europe	Unknown	FÖ, PT-AZO	J6	mycophage	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967)
Atomaria bella Reitter, 1875	detriti-vorous	Europe, north Africa	1967, GB	GB	G3	mycophage	Duff (2008)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Atomaria fuscata (Schönherr, 1808)	detriti-vorous	Europe	Unknown	GB	U	mycophage; also adults damaging beet	Duff (2008), Falcoz (1929)
Atomaria fuscipes (Gyllenhal, 1808)	detriti-vorous	Europe	Unknown	GB	U	mycophage; also adults damaging beet	Duff (2008), Falcoz (1929), Freude et al. (1967)
Atomaria hislopi Wollaston, 1857	detriti-vorous	Northern Europe	Unknown	GB	U	mycophage	Duff (2008), Falcoz (1929)
Atomaria lohsei Johnson & Strand, 1968	detriti-vorous	Central Europe, Spain	1976, GB	GB	G3	rotten wood debris abroad; mainly conifer forest	Duff (2008)
Atomaria munda Erichson, 1846	detriti-vorous	Eurasia	Unknown	PT-AZO, GB	J1	attic	Borges et al. (2005), Falcoz (1929), Freude et al. (1967)
Atomaria nitidula Marsham, 1802	detriti-vorous	Europe, north Africa	Unknown	GB	J1	mycophage	Duff (2008), Falcoz (1929)
Atomaria punctithorax Reitter, 1887	detriti-vorous	Central, Northern Europe	Unknown	GB	J1	mycophage	Duff (2008)
Atomaria pusilla (Paykull, 1798)	detriti-vorous	Europe, north Africa	Unknown	IE, GB	J2, I2	mycophage	Duff (2008), Falcoz (1929), Freude et al. (1967)
Atomaria strandi Johnson, 1967	detriti-vorous	Central, southern Europe	Unknown	IE, GB	J1	mycophage	Duff (2008)
Atomaria testacea Stephens, 1830	detriti-vorous	Europe	Unknown	GB	J1	mycophage	Duff (2008), Falcoz (1929)
Atomaria turgida Erichson, 1846	detriti-vorous	Northern, Central Europe	1996, IE, GB	IE, GB	G3	mycophage	Duff (2008), Falcoz (1929), Freude et al. (1967)
Cryptophagus dentatus (Herbst, 1793)	detriti-vorous	Palaearctic	1937, PT-MAD	PT-AZO, PT-MAD	J1	flour, dry fruits	Borges et al. (2005), Duff (2008), Falcoz (1929), Freude et al. (1967), Mendonça and Borges (2009)
Cryptophagus distinguendus Sturm 1845	detriti-vorous	Europe, Asia, Africa	Unknown	FÖ	J1	mills, stored products	Bengtson (1981), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptophagus saginatus Sturm, 1845	detriti-vorous	Europe, North Africa	Unknown	PT-AZO	J1	attic	Borges (1990), Borges et al. (2005), Falcoz (1929), Freude et al. (1967), Mendonça and Borges (2009)
Cryptophagus scanicus (Linnaeus, 1758)	detriti-vorous	Europe	Unknown	FÖ	J1	grain, dry fruits	Bengtson (1981), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967)
Cryptophagus schmidti Sturm, 1845	detriti-vorous	Eurasia	Unknown	PT-AZO	J1	mammals and *Vespa* nests	Borges et al. (2005), Falcoz (1929), Freude et al. (1967)
Ephistemus globulus Paykull, 1798	detriti-vorous	Europe	Unknown	IE, PT-AZO, GB	G1	ground, salix basis	Borges et al. (2005), Duff (2008), Falcoz (1929), Mendonça and Borges (2009)
Dermestidae							
Attagenus bifasciatus (Olivier, 1790)	detriti-vorous	southern Europe, Minor Asia	Unknown	DK	J1, E	stored products	
Attegenus brunneus Faldermann, 1835	detriti-vorous	Medi-terranean region	Unknown	CH, GB	J1	domestic	Duff (2008), Freude et al. (1979)
Attegenus pellio Linnaeus, 1758	detriti-vorous	Europe	Unknown	IE, GB	J1, E5, I2	animal materials	Freude et al. (1979)
Attagenus quadrimaculatus Kraatz, 1858	detriti-vorous	southern Europe, Minor Asia	Unknown	CH	J1	domestic	Freude et al. (1979), Wittenberg et al. (2006)
Attagenus rossi Ganglbauer, 1904	detriti-vorous	Cosmo-politan (native? Europe, Africa, USSR)	Unknown	CH	J1	domestic	Wittenberg et al. (2006)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Attagenus simplex Reitter, 1881	detriti-vorous	North Africa, Italy	Unknown	SE	J	stored products	
Attagenus trifasciatus (Fabricius, 1787)	detriti-vorous	Medi-terranean region	Unknown	DE, GB	J	stored products	Freude et al. (1979), Hermann and Baena (2004)
Anthrenus coloratus Reitter, 1881	detriti-vorous	East Medi-terranean region	1983, GB	AT, GB	J1, E	skins, stuffed animals	Duff (2008), Freude et al. (1979)
Anthrenus festivus Erichson, 1846	detriti-vorous	Medi-terranean region	Unknown	AT, CH	J1, E	insects in collection; adults on flowers	Freude et al. (1979), Wittenberg et al. (2006)
Anthrenus museorum (Linnaeus, 1761)	detriti-vorous	Holarctic	Unknown	PT-AZO	J1, E	insects in collection	Borges et al. (2005), Freude et al. (1979)
Anthrenus olgae Kalik, 1946	detriti-vorous	Central Europe	Unknown	AT, GB	J1, E	stored products	Duff (2008), Freude et al. (1979)
Dermestes murinus Linnaeus, 1758	detriti-vorous	Europe	Unknown	PT-AZO, ES-CAN	J	domestic on animal products	Borges et al. (2005), Freude et al. (1979), Machado and Oromi (2000)
Dermestes undulatus Brahm, 1790	detriti-vorous	Holarctic	Unknown	LV, PT-AZO, ES-CAN	J	domestic on animal products	Borges et al. (2005), Freude et al. (1979), Machado and Oromi (2000), Mendonça and Borges (2009)
Derodontidae							
Laricobius erichsonii Rosenhauer, 1846	parasitic/ predator	europe (imported to USA)	1971, GB	GB	G3	aphid predator	Franz (1958), Freude et al. (1979)
Elateridae							
Athous haemorrhoidalis (Fabricius, 1801)	phyto-phagous	Western, central, Northern Europe	Unknown	PT-AZO	E5	roots cereals, potato	Borges et al. (2005), Laibner (2000), Leseigneur (1972)
Melanotus dichrous (Erichson, 1841)	phyto-phagous	southern Europe	Unknown	PT-AZO	F5	shrubs	Borges et al. (2005), Leseigneur (1972), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Histeridae							
Acritus nigricornis (Hoffmann, 1803)	parasitic/ predator	Palaearctic	Unknown	PT-AZO, ES-CAN	E	cow, horse dung	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Halacritus punctum (Aube, 1843)	parasitic/ predator	europe south	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Hypocaccus dimidiatus (Illiger, 1807)	parasitic/ predator	Medi-terranean Region	Unknown	PT-AZO	B1	cadavers, feces, vegetal decays, sandy soil	Borges et al. (2005), Mendonça and Borges (2009)
Macrolister major (Linnaeus, 1767)	parasitic/ predator	Medi-terranean Region	Unknown	DK	B1	cow dung, nr litoral	Mazur (1989)
Saprinus acuminatus (Fabricius, 1798)	parasitic/ predator	euro-centrosasiatic	Unknown	PT-AZO	U	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Saprinus caerulescens (Hoffmann, 1803)	parasitic/ predator	Europe	Unknown	PT-AZO	U	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005)
Saprinus planiusculus Motschulsky, 1849	parasitic/ predator	palaearctic	Unknown	PT-AZO	B	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Saprinus semistriatus (Scriba, 1790)	parasitic/ predator	palaearctic	Unknown	PT-AZO	B	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Saprinus subnitescens Bickhardt, 1909	detriti-vorous	Europe	Unknown	PT-AZO	B	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Hydrophilidae							
Cercyon depressus Stephens, 1829	parasitic/ predator	Northern, Central Europe	Unknown	PT-AZO	B	rotting seaweed on seashores	Borges et al. (2005), Mendonça and Borges (2009)
Cercyon haemorhoidalis (Fabricius, 1775)	parasitic/ predator	Europe	Unknown	PT-AZO	J6	decaying organic matter, flood debris	Borges et al. (2005), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Cercyon obsoletus (Gyllenhal, 1808)	parasitic/ predator	Northern, Central Europe	Unknown	PT-AZO	U	mainly in dung of larger herbivores, but also recorded from arrion and manure	Vorst (2009)
Cercyon quisquilius (Linnaeus ,1761)	unknown	Europe	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Enochrus bicolor (Fabricius, 1792)	unknown	All over Europe	Unknown	PT-AZO	B	halophil	Borges et al. (2005), Mendonça and Borges (2009)
Helochares lividus (Forster, 1771)	parasitic/ predator, phyto-phagous	central, western, southern Europe	Unknown	PT-AZO	C1, D	in standing waters	Borges et al. (2005)
Sphaeridium bipustulatum Fabricius, 1781	parasitic/ predator	Western, Central Europe	Unknown	PT-AZO	E	mammal dung, decaying organic matter, fungi, and on plant sap	Borges et al. (2005), Mendonça and Borges (2009)
Sphaeridium scarabaeoides (Linnaeus, 1758)	parasitic/ predator	Eurasia	Unknown	PT-AZO	E	dung	Borges et al. (2005)
Kateretidae							
Brachypterolus antirrhini (Murray, 1864)	phyto-phagous	Medi-terranean Region	1926, GB	BE, LI, LU, NL, GB	E, I2	*Antirrhinum*, *Linaria*	Audisio (1993), Borges et al. (2005), Duff (2008)
Brachypterolus vestitus (Kiesenwetter, 1850)	phyto-phagous	West Medi-terranean Region	1929, GB	AT, BE, CZ, DE, LI, CH, GB	E, I2	*Antirrhinum*, *Linaria*	Audisio (1993), Duff (2008), Šefrova and Lastuvka (2005)
Laemophloeidae							
Cryptolestes capensis (Waltl, 1834)	detriti-vorous	Medi-terranean Region	1962, CZ	AL, AT, BE, CZ, DK, FI, DE, HU, PL, SE, UA, GB	J1	grain and grain products, nuts, oilseeds, dried root crops	Borges et al. (2005), Duff (2008), Šefrova and Lastuvka (2005)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Latridiidae							
Cartodere norvegica (Strand, 1940)	detriti-vorous	Europe	Unknown	PT-AZO, PT-MAD	FB	under populus bark	Borges et al. (2005), Rücker (1995)
Corticaria abietorum Motschulsky, 1867	detriti-vorous	Central northern Europe	Unknown	PL, GB	G3	conifer specialist (douglas-fir, abies)	Freude et al. (1967)
Dienerella ruficollis (Marsham, 1802)	detriti-vorous	Medi-terranean region	1889, GB	DE, IT-SIC, PT-AZO, GB	J1	dry plants, flour	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008)
Thes bergrothi (Reitter, 1880)	detriti-vorous	northeastern Europe	Unknown	GB	I, J	on fungus, on decaying plant material, attic; flour, dattes	Duff (2008)
Leiodidae							
Catops fuliginosus Erichson 1837	detriti-vorous	Western, Central, Southern Europe	Unknown	FÖ	F	fungi	Bengtson (1981), Duff (2008)
Meloidae							
Mylabris variabilis (Pallas, 1781)	parasitic/ predator, phyto-phagous	Eurasia	Unknown	IT-SAR	E	adult floricolous, parasite Acrididae	
Malachiidae							
Axinotarsus marginalis (Laporte de Castelnau, 1840)	detriti-vorous	Europe	Unknown	GB	G	saproxilic/ woodland	Duff (2008)
Monotomidae							
Monotoma bicolor A. Villa & G. B. Villa, 1835	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	E, J	mole nest, vegetal waste	Borges et al. (2005)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Monotoma longicollis (Gyllenhal, 1827)	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	J, J6	vegetal waste	Borges et al. (2005), Mendonça and Borges (2009)
Monotoma picipes Herbst, 1793	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	J, J6	saprophage/ mycophage; vegetal waste	Borges et al. (2005), Mendonça and Borges (2009)
Monotoma quadrifoveolata Aube, 1837	detriti-vorous	Eurasia	2005, PT-AZO	PT-AZO	J, J6	decaying grains	Borges et al. (2005)
Monotoma spinicollis Aubé, 1837	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	J	paddy residues, paddy storage	Borges et al. (2005), Mendonça and Borges (2009)
Rhizophagus grandis Gyllenhal, 1827	parasitic/ predator	Europe	1983, GB	GB	G3	predator *Dendroctonus- Picea* stands	Bouget and Moncoutier (2003), Duff (2008)
Mycetophagidae							
Berginus tamarisci Wollaston, 1854	detriti-vorous	southern Europe, Canary Isls	Unknown	AT, CH	G3	*Tamarix*, on pine	Borges et al. (2005), Freude et al. (1967)
Eulagius filicornis (Reitter, 1887)	detriti-vorous	southern France, North Africa	1993, GB	GB	G3	with the fungus *Stereum hirsutum* growing on dead branches of broad-leaved trees.	Duff (2008)
Nitidulidae							
Carpophilus quadrisignatus Erichson, 1843	phyto-phagous, detrivorous	Medi-terranean region	2000, DE	AT, DE, PT-AZO	J1	dry fruits	Audisio (1993), Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009)
Epuraea aestiva (Linnaeus, 1758)	detriti-vorous	Europe, Asia	2005, PT-AZO	PT-AZO	G, I		Audisio (1993), Borges et al. (2005)
Epuraea biguttata (Thunberg, 1784)	detriti-vorous	Northern Europe	2005, PT-AZO	PT-AZO	J1, I	mushrooms	Audisio (1993), Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Epuraea longula Erichson, 1845	detriti-vorous	Eurasia	2005, PT-AZO	PT-AZO	J		Audisio (1993), Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)
Meligethes aeneus (Fabricius, 1775)	phyto-phagous	Europe	2005, PT-AZO	PT-AZO, ES-CAN	I1	rape, rosaceae, pollen-feeding	Audisio (1993), Borges et al. (2005), Duff (2008), Freude et al. (1967), Machado and Oromi (2000), Mendonça and Borges (2009)
Meligethes incanus Sturm, 1845	phyto-phagous	Southeastern Europe	1867, PT-AZO	PT-AZO, GB	FA, E5	*Nepeta cataria*	Audisio (1993), Borges et al. (2005)
Nitidula flavomaculata Rossi, 1790	detriti-vorous	southern Europe	1900, CZ	CZ	J1, J6	bones vertebrates	Audisio (1993), Freude et al. (1967), Šefrova and Lastuvka (2005)
Pocadius adustus Reitter, 1888	detriti-vorous	Eurasia	2004, GB	GB	E2	epigeous gastermyctes specialist	Audisio (1993), Duff (2008)
Oedemeridae							
Nacerdes melanura (Linnaeus, 1758)	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	B	driftwood on beaches, moist wood	Borges et al. (2005), Mendonça and Borges (2009)
Phalacridae							
Phalacrus corruscus (Panzer, 1797)	phyto-phagous	Europe	Unknown	PT-AZO	I	seeds of yellow sowthistle *Sonchus arvensis*	Borges et al. (2005)
Ptiliidae							
Acrotrichis cognata (Matthews, 1877)	detriti-vorous	Europe	1932, SE	AT, DK, FI, DE, IE, NL, NO, SE, GB	E5, J6	dung, rotting fungi, carcasses, compost near forests	Duff (2008), Freude et al. (1971)
Actinopteryx fucicola (Allibert, 1844)	detriti-vorous	Europe	Unknown	PT-AZO	U	unknown	Borges et al. (2005), Mendonça and Borges (2009)
Ptenidium pusillum (Gyllenhal, 1808)	detriti-vorous	Europe	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Scarabaeidae							
Onthophagus illyricus (Scopoli, 1763)	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	E	dung	Baraud (1992), Borges et al. (2005), Bunalski (1999), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Onthophagus taurus (Schreber, 1759)	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	E	dung	Baraud (1992), Borges et al. (2005), Bunalski (1999), Mendonça and Borges (2009)
Onthophagus vacca (Linnaeus, 1767)	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	E	dung	Baraud (1992), Borges et al. (2005), Bunalski (1999), Mendonça and Borges (2009)
Oryctes nasicornis (Linnaeus, 1758)	detriti-vorous	southern Europe	1880, DK	DK, FI, HU, LT, NO, SE	J	saprophagous, compost	Baraud (1992), Bunalski (1999)
Scydmaenidae							
Stenichnus collaris (Muller & Kunze, 1822)	detriti-vorous	Europe	Unknown	FÖ	I2	mosses, leaves	Bengtson (1981)
Silphidae							
Ablattaria laevigata (Fabricius, 1775)	parasitic/ predator	Western & southcentral Europe	Unknown	EE	E, I1	snail predator, fields	
Aclypea opaca (Linnaeus, 1758)	phyto-phagous	Central, Northern, Eastern Europe	2005, PT-AZO	PT-AZO	E, I1	chenopodiacées	Borges et al. (2005)
Silvanidae							
Silvanus unidentatus (Olivier, 1790)	detriti-vorous	Europe	Unknown	PT-AZO	J1		Borges et al. (2005), Mendonça and Borges (2009)
Sphindidae							
Sphindus dubius (Gyllenhal, 1808)	detriti-vorous	europe	2005, PT-AZO	PT-AZO	U	mycophage	Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009)
Staphylinidae							
Aleochara bipustulata (Linnaeus, 1761)	parasitic/ predator	Palaearctic	Unknown	PT-AZO	I	solitary ectoparasitoids of cyclorrhaphous Diptera (*Delia*)	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Aleochara clavicornis Redtenbacher, L., 1849	parasitic/ predator	Palaearctic	2005, PT-AZO	PT-AZO	I1, J6	feed on decaying meat, fly maggots and also on fly puparia	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Aleochara sparsa Heer, 1839	parasitic/ predator	Europe	Unknown	FÖ	I1, J	predator of cyclorrhaphous Diptera (*Musca*) in stables	Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Amischa analis (Gravenhorst, 1802)	parasitic/ predator	Italy	Unknown	PT-AZO	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Anotylus nitidulus (Gravenhorst 1802)	parasitic/ predator	Europe, cosmopolitan	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Anotylus speculifrons (Kraatz 1857)	parasitic/ predator	Europe, Asia Minor, North Africa	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Atheta acuticollis Fauvel, 1907	parasitic/ predator	palaearctic	2005, PT-AZO	PT-AZO	U		
Atheta amicula (Stephens,1832)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO, PT-MAD, ES-CAN	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000)
Atheta atramentaria (Gyllenhal,1810)	parasitic/ predator	Europe	Unknown	PT-AZO, PT-MAD, ES-CAN	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta castanoptera (Mannerheim, 1830)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta coriaria (Kraatz, 1858)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO, ES-CAN	U	predator, biological control soil-dwelling larvae of small Diptera	Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Atheta divisa (Maerkel, 1844)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	U	bird and animal nest	Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta fungi (Gravenhorst,1806)	parasitic/ predator	Europe	Unknown	FÖ, PT-AZO, PT-MAD, ES-CAN	I1	predator, carrot fields	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta gregaria (Casey, 1910)	parasitic/ predator	europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Atheta harwoodi Williams, 1930	parasitic/ predator	europe	Unknown	FÖ, GB	J6	bird nest, compost	Bengtson (1981), Duff (2008), Enckell et al. (1987), Freude et al. (1974)
Atheta luridipennis (Mannerheim, 1830)	parasitic/ predator	Central, Northern Europe	2003, ES	FÖ, PT-AZO, ES	C3	streambanks	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Freude et al. (1974), Mendonça and Borges (2009)
Atheta nigra (Kraatz,1856)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta nigricornis (Thomson,1852)	parasitic/ predator	Northern Europe	Unknown	FÖ	U	fungi *Meripilus giganteus*	Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Atheta oblita (Erichson,1839)	parasitic/ predator	Northern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta palustris (Kiesenwetter,1844)	parasitic/ predator	Morocco, France Italy	2005, PT-AZO	PT-AZO, PT-MAD	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta sordida Marsham,1802	parasitic/ predator	southern Europe, Minor Asia	2005, PT-AZO	PT-AZO, PT-MAD, ES-CAN	U		Borges (1990), Freude et al. (1974), Mendonça and Borges (2009)
Atheta triangulum (Kraatz,1856)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Atheta trinotata (Kraatz,1856)	parasitic/ predator	europe	Unknown	FÖ, PT-MAD, ES-CAN	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974), Machado and Oromi (2000)
Bisnius sordidus (Gravenhorst, 1802)	parasitic/ predator	Europe, Asia, North Africa	2005, PT-AZO	PT-AZO	I, J6	compost, predator	Borges et al. (2005), Mendonça and Borges (2009)
Brachygluta paludosa (Peyron, 1858)	unknown	Minor Asia, Bulgaria	Unknown	DK	U		
Cafius xantholoma (Gravenhorst, 1806)	unknown	Europe, Asia, Africa	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Cordalia obscura (Gravenhorst,1802)	unknown	Northern Europe	Unknown	PT-AZO, PT-MAD, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Creophilus maxillosus (Linnaeus, 1758)	unknown	Europe (intro NAm)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Cypha pulicaria (Erichson,1839)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Edaphus beszedesi Reitter, 1914	detriti-vorous	southern Europe	Unknown	AT, EE, CH	J6	compost, rotting plant material	Luka et al. (2009), Wittenberg et al. (2006)
Euplectus infirmus Raffray, 1910	unknown	Southern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Gabrius nigritulus (Gravenhorst, 1802)	unknown	Eurasia	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Gabronthus thermarum (Aubé, 1850)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	I, J6	compost, predator	Borges et al. (2005), Mendonça and Borges (2009)
Gyrophaena bihamata Thomson,1867	unknown	Central, Northern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Gyrophinus fracticornis (O. Müller, 1776)	unknown	euroMedi-terranean	2005, PT-AZO	PT-AZO	J6	waste, decay	Borges et al. (2005), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Hadrognathus longipalpis (Mulsant & Rey, 1851)	unknown	Western Europe	1989, GB	GB	G, J6	humus	Duff (2008)
Halobrecta flavipes Thomson,1861	unknown	Northern, Central Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Heterota plumbea (Waterhouse,1858)	unknown	Europe	2005, PT-AZO	PT-AZO, PT-MAD, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Lathrobium fulvipenne (Gravenhorst, 1806)	unknown	Northern and Central Europe, siberia	Unknown	FÖ	D	bogs, mires, wet fields	Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Leptacinus pusillus (Stephens, 1833)	unknown	Europe (introAF, AUS)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Lithocharis ochracea (Gravenhorst, 1802)	unknown	Eurasia	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Micropeplus marietti Jacquelin du Val, 1857	unknown	Southern Europe, Caucasus	Unknown	AT, CH	J6	rotten vegetals	Luka et al. (2009), Wittenberg et al. (2006)
Mycetoporus nigricollis (Stephens, 1832)	unknown	Europe	Unknown	ES-CAN	J6	rotten vegetals	Machado and Oromi (2000)
Myllaena brevicornis (Matthews,1838)	unknown	Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Myrmecopora sulcata (Kiesenwetter,1850)	unknown	Europe	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Myrmecopora uvida (Erichson, 1840)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Neobisnius lathrobioides (Baudi, 1848)	unknown	Europe (intro NAm)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Neobisnius procerulus (Gravenhorst, 1806)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005)
Ocalea picata (Stephens,1832)	unknown	Northern, Central Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Oligota pusillima (Gravenhorst,1806)	parasitic/ predator	Northern Europe	2005, PT-AZO	PT-AZO	U	mite predator	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Olophrum fuscum (Gravenhorst, 1806)	unknown	Northern & Central Europe	Unknown	FÖ	D	bogs	Bengtson (1981), Enckell et al. (1987)
Omalium excavatum Stephens, 1834	unknown	Europe, caucasus	Unknown	FÖ	E, J	nests micromammals	Bengtson (1981), Enckell et al. (1987)
Omalium rivulare (Paykull, 1789)	unknown	Europe	Unknown	FÖ	J6	vegetal decay	Bengtson (1981), Enckell et al. (1987)
Oxypoda haemorrhoa (Mannerheim, 1830)	unknown	Northern, Central Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Oxytelus sculptus Gravenhorst, 1806	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Phacophallus parumpunctatus (Gyllenhal, 1827)	unknown	Europe	1854, IE	IE, PT-AZO, GB	U		Anderson (1997), Borges et al. (2005), Duff (2008), Mendonça and Borges (2009)
Philonthus cephalotes (Gravenhorst, 1802)	parasitic/ predator	Holarctic	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Philonthus concinnus (Gravenhorst, 1802)	parasitic/ predator	Eurasia (intro Nam)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Philonthus discoideus (Gravenhorst, 1802)	parasitic/ predator	Eurasia, North Africa	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Philonthus fenestratus Fauvel, 1872	parasitic/ predator	Europe, caucasus	2005, PT-AZO	PT-AZO	U		Borges et al. (2005)
Philonthus fimetarius (Gravenhorst, 1802)	parasitic/ predator	Palaearctic	Unknown	FÖ	G		Bengtson (1981), Enckell et al. (1987)
Philonthus longicornis Stephens, 1832	parasitic/ predator	Eurasia	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Philonthus marginatus (O. Muller, 1764)	parasitic/ predator	Europe, Siberia	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Philonthus politus (Linnaeus, 1758)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	E		Borges et al. (2005), Mendonça and Borges (2009)
Philonthus quisquiliarius (Gyllenhal, 1810)	parasitic/ predator	Eurasia, North Africa	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Philonthus umbratilis (Gravenhorst, 1802)	parasitic/ predator	Europe (intro NAm)	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Phloeopora angustiformis Baudi, 1870	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Phloeopora teres (Gravenhorst, 1802)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Phloeopora testacea (Mannerheim, 1830)	unknown	Northern Europe	2005, PT-AZO	PT-AZO	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Proteinus brachypterus (Fabricius, 1792).	detriti-vorous	Palaearctic	Unknown	FÖ	J6	rotten vegetals	Bengtson (1981), Enckell et al. (1987), Gamarra and Outerelo (2009)
Quedius mesomelinus (Marsham, 1802)	parasitic/ predator	Alps, Central Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Remus pruinosus (Erichson, 1840)	parasitic/ predator	southern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Geostiba circellaris (Gravenhorst, 1806)	unknown	Europe	Unknown	FÖ	E,G1		Freude et al. (1974)
Sunius propinquus (Brisout de Barneville, 1867)	unknown	Europe	Unknown	PT-AZO	U		Borges et al. (2005), Freude et al. (1974)
Tachinus laticollis Gravenhorst, 1802	detriti-vorous	Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Tachinus signatus Gravenhorst, 1802	unknown	Europe (intro NAm)	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Tachyporus chrysomelinus (Linnaeus, 1758)	unknown	Eurasia	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Tachyporus nitidulus (Fabricius, 1781)	unknown	Europe (Int AUS)	2005, PT-AZO	PT-AZO	U		Mendonça and Borges (2009)
Thecturota marchii (Dodero,1922)	detriti-vorous	Southern Europe	Unknown	AT, DK, EE, CH, GB	I,J6	waste land, compost	Luka et al. (2009), Wittenberg et al. (2006)
Xantholinus linearis (Olivier, 1795)	parasitic/ predator	All over Europe	Unknown	FÖ, PT-AZO	E, G, I2	stones, mosses, fungi	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Freude et al. (1974), Mendonça and Borges (2009)
Xantholinus longiventris Heer, 1839	parasitic/ predator	Europe	Unknown	PT-AZO	U		Borges et al. (2005)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Xylodromus concinnus (Marsham, 1802)	parasitic/ predator	Europe	Unknown	FÖ	G, F, I2, J1	forests, gardens, cellars	Bengtson (1981), Enckell et al. (1987)
Xylodromus depressus (Gravenhorst, 1802)	parasitic/ predator	Europe	Unknown	FÖ	G, I2	bark, wet wood	Bengtson (1981), Enckell et al. (1987)
Tenebrionidae							
Blaps gigas (Linnaeus, 1758)	detriti-vorous	Medi-terranean region	1888, CZ	CZ, DK, PT-AZO	J6		Borges et al. (2005), Šefrova and Lastuvka (2005)
Blaps lethifera Marsham, 1802	detriti-vorous	Europe	Unknown	PT-AZO, GB	J1, J2		Borges et al. (2005), Duff (2008)
Blaps mortisaga (Linnaeus, 1758)	detriti-vorous	Eastern and Central Europe	Unknown	GB	J1, J2	detrivorous	Duff (2008), Ferrer and Martinez Fernandez (2008)
Blaps mucronata Latreille, 1804	detriti-vorous	Europe, Medi-terranean	Unknown	IE, GB	J1, J2		Duff (2008)
Corticeus linearis (Fabricus, 1790)	detriti-vorous	Europe	Unknown	GB	G3	old broadleaved forests	Duff (2008)
Corticeus pini (Panzer, 1799)	detriti-vorous	Europe	Unknown	GB	G3		
Scaurus punctatus Fabricius, 1798	detriti-vorous	Medi-terranean region	Unknown	ES-CAN	U		Machado and Oromi (2000)
Tenebrio obscurus Fabricius, 1792	detriti-vorous	Europe	Unknown	IE, PT-AZO, ES-CAN, GB	J1, J2	stored products	Borges et al. (2005), Duff (2008), Machado and Oromi (2000)
Trachyscelis aphodioides Latreille, 1809	detriti-vorous	Medi-terranean region	Unknown	ES-CAN	J	stored products	Borges et al. (2005), Machado and Oromi (2000)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Throscidae							
Throscus dermestoides (Linnaeus, 1766)	detriti-vorous	Europe	2005, PT-AZO	PT-AZO	G	bark, in forest	Borges et al. (2005), Mendonça and Borges (2009), Freude et al. (1979)
Trogidae							
Trox scaber (Linnaeus, 1767)	detriti-vorous	Eurasia	2005, PT-AZO	PT-AZO	U	nests	Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)
Zopheridae							
Aulonium ruficorne (Olivier, 1790)	unknown	Medi-teranean	Unknown	GB	U		Duff (2008)

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True Bugs (Hemiptera, Heteroptera) Chapter 9.1

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Abstract

The inventory of the alien Heteroptera of Europe includes 16 species alien *to* Europe, 25 species alien *in* Europe and 7 cryptogenic species. This is approximately 1.7% of the Heteroptera species occurring in Europe. Most species belong to Miridae (20 spp.), Tingidae (8 spp.), and Anthocoridae (7 spp.). The rate of introductions has exponentially increased within the 20th century and since 1990 an approximate arrival rate of seven species per decade has been observed. Most of the species alien *to* Europe are from North America, almost all of the species alien *in* Europe originate in the Mediterranean region and were translocated to central and northern Europe. Most alien Heteroptera species are known from Central and Western Europe (Czech Republic, Germany, Netherlands, Great Britain). Ornamental trade and movement as stowaways with transport vehicles are the major pathways for alien Heteroptera. Most alien Heteroptera colonize habitats under strong human influence, like agricultural, horticultural, and domestic habitats, parks and gardens. A few species prefer woodland including plantations of non-native forest trees. Impacts of alien Heteroptera in Europe are poorly investigated. A few species are considered pests in agriculture, forestry, or on ornamentals. More research is needed for a better understanding of the ecological and economic effects of introduced Heteroptera.

Keywords

alien, non-native, Hemiptera, Heteroptera, Europe

9.1.1 Introduction

The Heteroptera, or true bugs, is a highly diverse insect taxon with approximately 42,300 described species worldwide, separated into seven infraorders and 75–89 families (Henry 2009, Schuh and Slater 1995). Their body size ranges from less than 1 mm to 10 cm. True bugs feed on many different resources (e.g., haemolymph of insects, blood of endotherms, fungi cytoplasma, phloem-, xylem- or parenchym-sap of mosses, ferns, monocotyledons, mostly dicotyledons, algae, the endosperm of seeds, plant pollen). Heteropterans live in virtually all terrestrial and aquatic ecosystems from Antarctic birds' nests to rainforest canopies, from the open surface of the ocean (almost uniquely for insects), to torrential and stagnant rivers, from ephemeral rain pools and phytotelmata to large lakes, and in aphotic caves and man-made buildings (Schuh and Slater 1995).

Among the characteristic features are the mouthparts, which evolved as sucking stylets for the uptake of liquid food and the injection of secretions from the salivary gland; restricted diets are commonly observed. Most species are phytophagous, some feed exclusively on particular plant species, genera or families, whereas others are polyphagous species feeding on dozens to hundreds of different host plants. Some species are of considerable economic concern in agriculture or (more rarely) forestry, many species are predatory and some are used as biocontrol agents against agricultural pests (Schaefer and Panizzi 2000).

Although some heteropteran species have reduced wings or wing musculature, and some are sexually dimorphic in this respect, many species are good flyers and capable of negotiating long distances. Subsequent spread after introduction by humans into a new area is commonly observed. Eggs and nymphs are translocated with host plants over long distances. Unlike the situation in many other Hemiptera, sexual reproduction prevails, with only one parthenogenetic species known in the European fauna, and depending on the species, one to several generations develop under temperate conditions. Many species deposit their eggs inside the host plant, which effectively fosters passive translocation and facilitates spread.

9.1.2 Methods

Previously published information on alien Heteroptera species is available for some countries, e.g., Germany (Geiter et al. 2002) but see Hoffmann (2003) for a critical review, Austria (Essl and Rabitsch 2002), Switzerland (Kenis 2005), Czech Republic (Kment 2006b, Šefrová and Laštùvka 2005), and the Azores (Borges et al. 2005). Comparison of these lists is hindered by the use of different terminology and criteria for selecting species. The first attempt at a comprehensive treatment of the alien Heteroptera of Europe was published recently Rabitsch (2008) and serves as basis for this work, but is supplemented by new data (up to May 2009 including a few works in press). The reader is referred to Rabitsch (Rabitsch 2008) for a more detailed account on the history of introductions for each species.

This present chapter deals with species alien *to* Europe and species alien *in* Europe, but excludes continental European species alien to European islands. For example, Borges et al. (2005) stated that *Tingis cardui* (Linnaeus, 1758) and *Gastrodes grossipes* (De Geer, 1773), which both feeding on non-native host plants, are alien to the Azores. On the contrary, Heiss & Péricart (2007) argued that *Aradus canariensis* Kormilev, 1954 may have been introduced to Mallorca. The anthropogenic contribution of some recent range changes of continental "European" species to Great Britain and to Scandinavia, and hence their alien status, is particularly difficult to identify. For example, Ødegaard & Endrestøl (2007) present three hypotheses, not mutually exclusive, for the recent occurrence of *Chilacis typhae* (Perris, 1857) in Norway. For the time being, only *Deraeocoris lutescens* is here considered alien in Sweden and Norway, but the status of additional species needs careful re-examination, e.g. *Pinalitus atomarius* (Meyer-Dür, 1843) in Sweden (Lindskog and Viklund 2000), *Chilacis typhae* and *Heterogaster urticae* (Fabricius, 1775) in Norway (Ødegaard and Endrestøl 2007). Kirby et al. (2001) review several similar cases for Great Britain.

9.1.3 Taxonomy of the alien Heteroptera of Europe

Alien Heteroptera are non-uniformly distributed across the seven infraorders. There are no alien species in Enicocephalomorpha and Dipsocoromorpha, the basal infraorders with 420 and 340 species worldwide, respectively. These predatory, usually tiny and fragile species live their secret lives in seclusion of riparian habitats and ground litter. No alien Gerromorpha are known in Europe; members of this predatory infraorder with more than 2100 species worldwide are commonly known as "Jesus-bugs" due to their ability to move on the surface of running and standing waters. Among Nepomorpha, the aquatic true bugs, with 2300 species worldwide, and Leptopodomorpha, the "shore bugs", with 380 species worldwide, there is a single alien species in each infraorder, *Trichocorixa verticalis* and *Pentacora sphacelata*, both originally from North America, being introduced to the western Mediterranean region. Most alien Heteroptera belong to the most species-rich infraorders Cimicomorpha (20,500 species worldwide, 37 alien species in/to Europe) and Pentatomomorpha (16,200 species worldwide, 9 alien species in/to Europe).

Within Hemiptera, Heteroptera constitute only a small fraction of alien species compared to aphids and scales (see chapters 9.2 and 9.3). At the end of the chapter, Table 9.1.1 and 9.1.2 list 48 Heteroptera species considered alien in this study of which 16 species are alien to Europe (i.e., species introduced from outside Europe), 25 species are alien in Europe (i.e., species introduced from one part of Europe to another), and seven cryptogenic species are of unknown origin. According to Aukema & Rieger (1995–2006), there are approximately 2860 Heteroptera species (including subspecies) in Europe, which means that 1.7% of the European fauna is alien.

At the family level, Miridae (20 spp.) and Tingidae (8 spp.) prevail, followed by Anthocoridae (7 spp.) and Lygaeidae *sensu lato* (5 spp.) (Figure 9.1.1). The systematic classification of Lygaeidae is still under discussion. While most heteropterists agree that Lygaeidae are paraphyletic (Henry 1997), there is no consensus on how to arrange them.

The most species-rich family is Miridae, both in the native and the non-native faunas. Species of nine families are represented in the alien fauna, which is only 10% of the known families worldwide. Genera with more than one alien species are *Amphiareus* (2), *Anthocoris* (2), *Corythucha* (2), *Deraeocoris* (2), *Orthotylus* (4), *Stephanitis* (4), and *Tuponia* (5). Whereas all alien species belong to families present in Europe, 10 genera (13 genera including the cryptogenics, asterisked here) are alien at the genus level (*Amphiareus*, *Belonochilus*, **Buchananiella*, *Corythucha*, *Halyomorpha*, **Nesidiocoris*, *Nezara*, *Pentacora*, *Perillus*, **Taylorilygus*, *Trichocorixa*, *Tropidosteptes*, *Tupiocoris*).

Anthocoridae

All Anthocoridae (flower bugs or minute pirate bugs) are small insects (< 5 mm body size) and most species are predatory, actively searching and hunting for their prey, which regularly consist of soft-bodied Sternorrhyncha. About 450 species are known at the world level (Henry 2009) of which 75 are considered native in Europe (Aukema and Rieger 1995–2006). The alien Heteroptera of Europe only include 4 species alien *to* Europe and 3 alien *in* Europe (Figure 9.1.1). Hence several species, especially in the genera *Anthocoris* and *Orius*, are successfully used commercially in biological control programs in greenhouses and sometimes in the wild, e.g., (Lattin 1999, Schaefer and Panizzi 2000). Apparently, only one species, the western and southern European *Orius laevigatus* is established outside its natural range in the Netherlands (Aukema and Loomans 2005) although these authors do not rule out the possibility that this species has shifted northwards due to climate change. Similarly, the true cause of the recent westward spread of the East-Palaearctic *Amphiareus obscuriceps* cannot definitely be identified. Although predatory, several anthocorid species are specialized to host plants, where they search for prey, e.g., *Anthocoris butleri* on *Buxus* and *A. sarothamni* on *Cytisus*. Both host plants are widely used as ornamentals and introduction of the Heteroptera with the host plants, as well as a range shift from western to eastern Europe, is possible. The origin of the pan-tropical *Buchananiella continua* is unknown. It is known from western Europe and appears to have spread both in Great Britain and in continental Europe (Aukema 2007, Aukema and Hermes 2009, Kirby 1999). Likewise, the origin of the cosmopolitan *Amphiareus constrictus* is unclear. It was introduced to the Netherlands (Aukema and Hermes 2009) and may further spread in Europe. The alien status of *Lyctocoris campestris* in Europe is debatable.

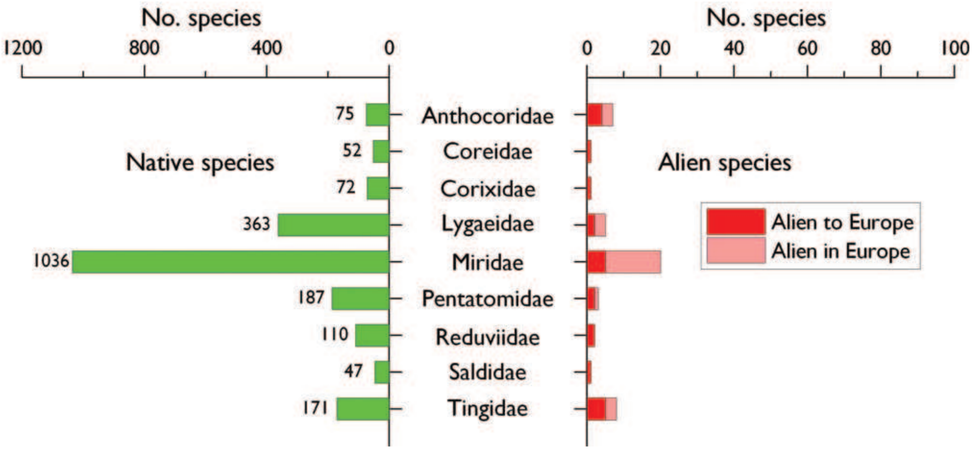

Figure 9.1.1. Taxonomic overview of the alien Heteroptera of Europe at the family level. Species alien *to* Europe include cryptogenics.

Coreidae

The leaf-footed or squash bugs is a species-rich family with species of medium to large body size. A total of 1900 species have been described throughout the world (Henry 2009), including 52 in Europe (Aukema and Rieger 1995–2006) but only one alien species has so far established on the continent. For several reasons, this single alien species, *Leptoglossus occidentalis*, is of particular interest. The native range is presumed to be west of the Rocky Mountains and following its spread in North America since the 1950s, it was introduced to Europe only in the late 1990s. The first date recorded in European record was 1999 in northern Italy (Bernardinelli and Zandigiacomo 2001) and the species rapidly spread over most of Europe (Dusoulier et al. 2007, Rabitsch 2008) with no foreseeable stop (Lis et al. 2008). This spread is likely to be the result of multiple introductions into Europe, and secondary translocations within it. When feeding on conifer seeds, fertility of the seeds is reduced, causing an economic impact for forestry. Recently, infrared receptive organs were found in *L. occidentalis*, orienting specimens towards conifer cones (Takács et al. 2009). Because individuals aggregate in autumn seeking hibernation sites in buildings, this species may also become a nuisance to people. Recently, it was found in Japan (Tokyo) (Ishikawa and Kikuhara 2009).

Corixidae

The family has about 600 described species in the world (Henry 2009), and 72 in Europe (Aukema and Rieger 1995–2006). The single aquatic species yet recognized as alien to Europe, *Trichocorixa verticalis*, is of nearctic origin and was introduced to

Europe (Portugal) between 1997 and 2003 (Sala and Boix 2005). Its pathway and potential impact is not known, but it may well have been introduced as a stowaway with mosquitofish (*Gambusia* sp.) and may outcompete native corixids and lead to a simplification of the aquatic community (Kment 2006a, Millán et al. 2005, Rodríguez-Pérez 2009).

Lygaeidae *sensu lato*

Lygaeidae or seed-bugs are a species-rich group of about 4000 species (Henry 2009) of medium body size that include both seed-feeding and predatory species with economic impact that is sometimes significant (Schaefer and Panizzi 2000). A total of 363 species are native to Europe (Aukema and Rieger 1995–2006) but only two species are alien to Europe, *Nysius huttoni* from New Zealand, and *Belonochilus numenius* from North America. Both species currently are locally distributed, but have the potential to spread over large parts of Europe. The former is known from the Netherlands, Belgium, northern France and Great Britain, where it occurs in ruderal sites, waste grounds and abandoned fields (Smit et al. 2007). *N. huttoni* feeds on several weeds and crops and attains pest status in its native area (Sweet 2000). The latter has been found in Corsica and mainland southern France in the vicinity of a railway station and at a university campus (Montpellier) (Matocq 2008) as well as in Catalonia, Spain (Castelldefels, Barcelona) (Gessé et al. 2009) on or near ornamental sycamore (*Platanus* sp.). These almost simultaneous findings and the fact that its host plant is regularly planted in urban parks and gardens, indicates that the species is already much more widely distributed and that further spread in Europe is very likely.

Three further lygaeid species are here considered alien in Europe. The first is *Arocatus longiceps*, an eastern Mediterranean species living on sycamore, whose occurrence is restricted to urban settings where it sometimes reaches high abundance causing a nuisance to people. Due to its variability, heteropterists debate its separation from native *Arocatus* species, considering possible hybridization and post-invasion colour changes (Hoffmann 2008). The second, *Orsillus depressus*, is a Mediterranean species living on Cupressaceae. Its adaptation to ornamental *Thuja*, *Chamaecyparis*, and *Juniperus* promoted its northward spread. Intraguild competition on native *Juniperus*-stands is likely, but so far not investigated. Lastly, *Oxycarenus lavaterae* is a western Mediterranean species living on Malvaceae s.l. with a preference for lime trees (*Tilia* sp.). The species builds spectacular large aggregations of millions of individuals, also sometimes causing nuisance to people, e.g., at market places in cities or when entering buildings.

Miridae

With more than 10,000 described species (Henry 2009) of which 1036 in Europe (Aukema and Rieger 1995–2006), Miridae or plant bugs is the most species-rich family within Heteroptera. Plant bugs include tiny to large, soft-bodied, dull to brightly coloured, phytophagous, zoophytophagous and predatory species (Wheeler 2001). Only 5 species alien *to* Europe have established whereas 15 species are considered alien *in* Europe (Figure 9.1.1.). Whereas some species are considered serious agricultural pests, others are used in biological control programmes. *Closterotomus trivialis* and *Dicyphus escalerae* are examples of Mediterranean species occurring locally in central Europe, the latter recently also found in Great Britain (Kirby et al. 2009), being introduced with their host plants. The same is most likely true for *Deraeocoris lutescens*, a western Palaearctic species introduced to Scandinavia. Another predatory, remarkably fast spreading species, is the Mediterranean *Deraeocoris flavilinea*, that presumably has been introduced unintentionally along transportation routes. *Tupiocoris rhododendri* was described from specimens collected in 1971 in Kew Gardens, London, but it originally comes from North America. Recently, this predatory species was found in continental Europe, and its further spread is to be expected (Aukema 2007, Aukema et al. 2005a). One of the most recent members of the European alien Heteroptera fauna is *Tropidosteptes pacificus* from North America, collected on European ash (*Fraxinus excelsior*) in a natural environment in the Netherlands (Aukema et al. 2009a). Three *Orthotylus* species live zoophytophagously on *Cytisus* and probably were introduced with their host plant to central and eastern Europe. The mediterranean *Orthotylus caprai* was only recently observed in central and western Europe on Cupressaceae, and is considered an alien species in Europe north of the Alps. Five *Tuponia* species, living phytophagously on *Tamarix*, were most likely introduced with their ornamental host plants.

Pentatomidae

Pentatomidae or stink bugs are a species-rich and medium to large body-sized heteropteran family with often stout and colourful bodies. About 4700 species have been recognized (Henry 2009), including 187 species in Europe (Aukema and Rieger 1995–2006). Members of one subfamily (Asopinae) are predatory and some are used in biocontrol programmes. This is true for *Perillus bioculatus*, native to North America and used against the Colorado potato beetles *Leptinotarsa decemlineata* in several European countries (De Clercq 2000). However, successful establishment in the wild apparently so far only occurred in Turkey and Greece. Recently, the Brown Marmorated Stink Bug *Halyomorpha halys*, native to Asia, was introduced to Switzerland (see factsheet 14.49) (Wermelinger e al. 2008). This species lives on ornamentals, vegetables and fruit trees where it may become a pest and it is regarded as a nuisance when seeking hibernation sites. The Southern Green Stink Bug *Nezara viridula*, a polyphytophagous pest species on several crops, is presumably of African and/or Mediterranean origin. *Nezara viridula* is a clear case of establishment of populations outside its original distribution in Germany, Hungary, Great Britain, and northern Switzerland. In addition, this species is found regularly in other parts of Europe, and is regularly intercepted by plant quarantine (Malumphy and Reid 2007).

Reduviidae

Reduviidae, the assassin bugs, are a species-rich and morphologically highly diverse predatory heteropteran family including 6900 species in the world (Henry 2009) of which 110 occur in Europe (Aukema and Rieger 1995–2006). However, only two cryptogenic, pantropical species are included here. *Empicoris rubromaculatus* is found in southwestern Europe with isolated records in Belgium, Croatia and Greece; the latter records may reflect a recent eastward range shift, but maybe this species was previously overlooked in the eastern Mediterranean region. *Ploiaria chilensis* is known from Macaronesia and Spain, with doubtful records from the central and eastern Mediterranean.

Saldidae

Shore bugs or Saldidae are a species-poor (340 species in the world (Henry 2009)), medium-sized, predatory family, living in littoral habitats along the edges of running and standing waters, marine shoreline and bogs. Whereas the native fauna includes 47 species (Aukema and Rieger 1995–2006), there is only one species alien to Europe. This single species, *Pentacora sphacelata*, is known since the 1950s from the Iberian Peninsula and Sardinia. This is a halophilous species living in the tidal-zone and close to saline waters.

Tingidae

Lace bugs or Tingidae are a species-rich, small-sized (< 8 mm body size), phytophagous family, with characteristic ornate and lacelike hemelytra and pronotum. Most species live on or near their host plants with a usually tight preference to particular plant species or families. About 2100 species are recognized in the world (Henry 2009) but only 171 are native to Europe (Aukema and Rieger 1995–2006). Thus, the alien fauna which includes 5 species alien to Europe is proportionally a little more important than in Miridae (2.9% of the total fauna vs. 0.5%; Figure 9.1.1). Both *Corythucha*-species were introduced from North America to Italy and live arboreally on their host plants, including the oak lace bug *C. arcuata* on *Quercus* (see factsheet 14.51) and the sycamore lace bug *C. ciliata* on *Platanus* (see factsheet 14.52). The former species was introduced a decade ago and only started to spread (Dioli et al. 2007), whereas the latter was introduced in the 1960s and nowadays is very widespread across Europe. *Stephanitis pyrioides* and *S. takeyai* were introduced from Japan and *S. rhododendri* from North America with ornamental Ericaceae (*Rhododendron*, *Azalea*, *Pieris*). *Dictyonota fuliginosa* and *Elasmotropis testacea* are both considered alien in parts of Europe where the host plants are also alien, although unambiguous evidence on their introduction status often is lacking. The alien status of *Stephanitis oberti* in Central Europe is debatable.

9.1.4 Temporal trends of introduction of alien Heteroptera in Europe

The (published) year when first recorded is known for all species (Table 9.1.1 and 9.1.2; see also Rabitsch (2008) for all country records), although it is evident that this need not be identical with the year of introduction. Usually it takes a few years for introduced insects to increase in abundance above a certain threshold to establish reproducing populations and to get recognized. This time-lag is known as a common characteristic of biological invasions and it can extend over long time periods in some organisms, e.g. decades or even centuries in some plants (Kowarik 1995). For insects, however, this time-lag usually extends over much shorter periods, but several years may still elapse since an alien species is discovered and information is communicated.

Some Heteroptera were already introduced in ancient times, such as the notorious bed bug *Cimex lectularius* Linnaeus, 1758 and maybe some others following human expansion associated with agricultural land reclamation. Those ancient introductions were rarely if ever documented and are therefore excluded in this study. However, there is no doubt that the rate of introductions has exponentially increased within the 20th century and reached unprecedented magnitudes in the 21st century (Figure 9.1.2). Since 1990, an approximate arrival rate of seven species per decade has been observed (Rabitsch 2008). Currently, Heteroptera alien *to* and alien *in* Europe both establish at a rate of 0.33 species per year; this means that on average every third year an Heteroptera species from outside Europe arrives in Europe. Even within the last eight years, five species have been detected: *Corythucha arcuata*, *Tropidosteptes pacificus* and *Belonochilus numenius* from North America (2000, 2007, 2008, respectively), *Nysius huttoni* from New Zealand (2002) and *Halyomorpha halys* from East Asia (2007).

Some species are suspected of having been introduced in the 19th century together with ornamental plants, e.g. *Anthocoris butleri* on *Buxus sempervirens*, *Anthocoris sarothamni*, *Orthotylus adenocarpi*, *O. concolor*, *O. virescens*, *Dictyonota fuliginosa* on *Cytisus scoparius*, and *Macrolophus glaucescens*, *Elasmotropis testacea* on *Echinops sphaerocephalus*. More recently, several *Tuponia* species were introduced with the increasing use of ornamental *Tamarix* species in public and private gardens.

The time of introduction for cryptogenic species into Europe is unclear and may well be several centuries before present. Most are pan-tropically distributed, zoophagous species.

9.1.5 Biogeographic patterns of the alien Heteroptera of Europe

9.1.5.1 Origin of alien species

A total of 16 species are alien to Europe, 10 of these from North America, 4 from the eastern Palaearctic and East Asia and one each from South America and Oceania. Almost all of the 25 species alien in Europe originate in the Mediterranean region and

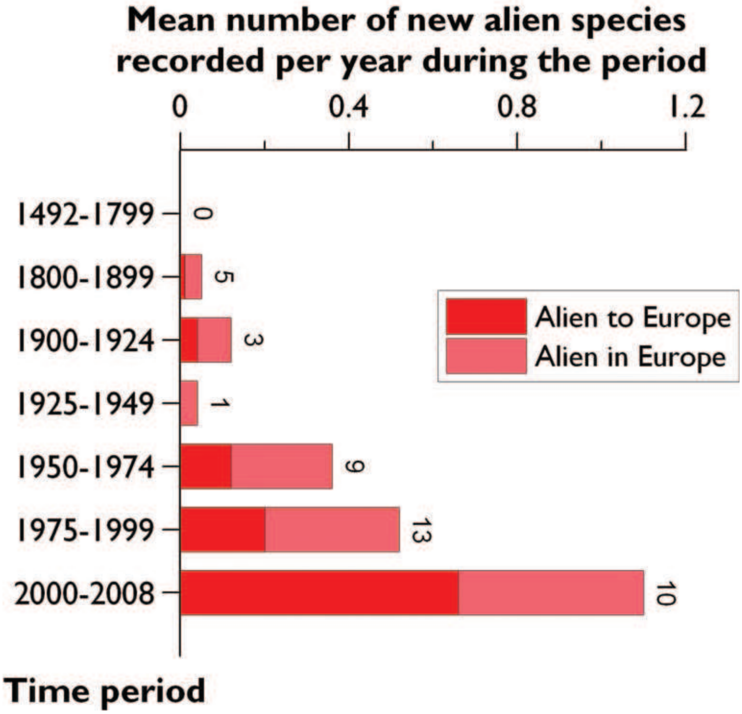

Figure 9.1.2. Temporal trends in the mean number of new records per year for Heteroptera species alien *to* Europe and alien *in* Europe from 1492 to 2008. Cryptogenic species are excluded. The number above the bar indicates the absolute number of species in this time period.

were translocated to central and northern Europe. Seven species are considered cryptogenic with unknown origin and cosmopolitan distribution (Figure 9.1.3).

Rabitsch (2008) mentioned the increasing trend of North American species arriving in Europe (Figure 9.1.4). This is corroborated by the most recent introductions of *Tropidosteptes pacificus* in the Netherlands (Aukema et al. 2009a) and *Belonochilus numenius* in Corsica, continental France and Spain (Gessé et al. 2009, Matocq 2008). Few species have been introduced from Oceania (New Zealand, *Nysius huttoni,* see factsheet 14.47) and South America (*Fulvius borgesi*). The latter species was only recently described as new to science, based on specimens collected in banana plantations at low altitudes on the Azores (Chérot et al. 2006). The authors argued, based on morphological characters, that the species was introduced from South America. *Nezara viridula* is considered the only alien species of African origin, although some were previously intercepted during plant health inspections, e.g. the Grain Chinch Bug, *Macchiademus diplopterus* (Distant, 1903) (Lygaeidae) and *Natalicola pallidus* (Westwood, 1837) (Tessaratomidae) at Heathrow Airport, London, on fruits and plants imported from South Africa (Malumphy and Reid 2007, 2008). Suitable climate seems to be a significant factor for the establishment of Heteroptera alien to Europe since 87% (14 species) come from temperate climates and only two species were introduced from the southern hemisphere.

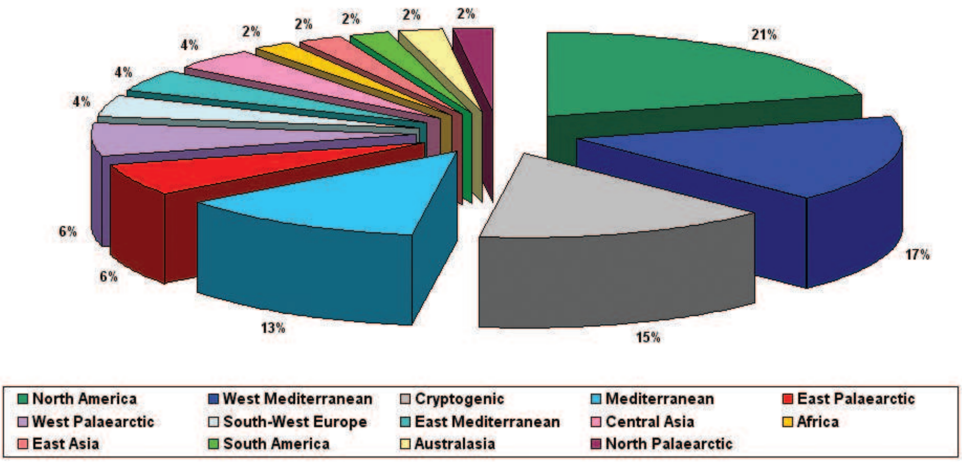

Figure 9.1.3. Geographic origin of the alien Heteroptera species of Europe.

9.1.5.2 Distribution of alien species in the European countries

Most alien Heteroptera species are known from Central Europe (Czech Republic: 22 species, that is 47% of all species, Germany: 20 species) and Western Europe (Netherlands: 20 species, Great Britain: 17 species) (Figure 9.1.5). One reason for the subordinate relevance of South Europe as a recipient for alien Heteroptera lies in the fact that almost all species alien *in* Europe originate in the Mediterranean region and were translocated north. This is likely a consequence of the increasing north-south exchange of people and merchandise (e.g., summer holiday tourism, fruits, vegetables) (Rédei and Torma 2003). A west-east pattern, however, can be found in suspected previous introductions of species living on western European ornamental plants, which were later widely planted across Europe. This concerns species living on *Buxus sempervirens*, *Cytisus scoparius*, and *Echinops* spp. Those plants are nowadays widely planted in cemeteries and private gardens and host monophagous Heteroptera species (e.g. *Anthocoris butleri*, *A. sarothamni*, *Dictyonota fuliginosa*, *Elasmotropis testacea*, *Macrolophus glaucescens* and *Orthotylus* spp.).

This northwest-southeast gradient is also demonstrated by a significant negative rank correlation of alien species numbers and longitude when the diversity of alien heteropterans is tentatively correlated to environmental and economic variables using a Spearman rank correlation (ϱ= -0.548; P < 0.001; Rabitsch, unpublished data). Whereas the number of native Heteropteran species per country appears to be significantly correlated with both the number of native plant species (ϱ= 0.887; P < 0.001) and the country size (ϱ= 0.576; P < 0.001), the number of alien Heteroptera species does not (ϱ= -0.548 and ϱ= 0.093, respectively, n.s.). On the contrary, whereas the number of alien Heteroptera is positively correlated with some economic variables (GDP per capita, ϱ = 0.417; P < 0.01; average trade import 1990–1997, ϱ= 0.748;

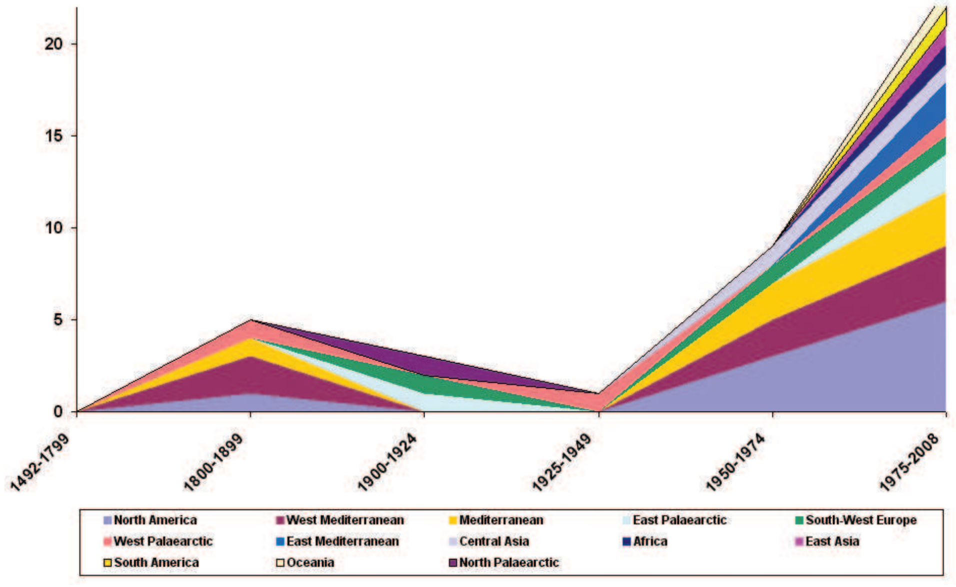

Figure 9.1.4. Numbers of established alien Heteroptera species of Europe by period of introduction and geographic origin. Cryptogenic species are excluded.

P < 0.001), the number of native species is not (ϱ= -0.049, n.s.). The distribution patterns of alien Heteropterans also seem to match these of alien plants (ϱ= 0.394; P<0.05) and alien terrestrial invertebrates (ϱ= 0.703; P<0.001); this likely is a fact of the overwhelming importance of urbanisation and trade import for the establishment of alien terrestrial invertebrate species in Europe (Roques et al. 2008). The Netherlands must be regarded as an invasion focus for the alien Heteroptera of Europe, with seven species having been first recorded in this country (Tables 9.1.1 and 9.1.2). A more sophisticated statistical analysis with several explanatory variables and taking into account area and sample effects, autocorrelation, multicollinearity, etc. will be presented elsewhere (Rabitsch and Moser, in prep.).

9.1.6 Pathways of introduction of the alien species of Heteroptera

Heteroptera are rarely intercepted (Roques and Auger-Rozenberg 2006) or at least rarely reported, in part due to their ancillary role as pest organisms. Recently, however, a number of such cases were published from regular plant health inspections in Great Britain. For example, *Natalicola pallidus* (Tessaratomidae) was found on *Crassula multicava* from South Africa (Malumphy and Reid 2008) and one specimen of *Leptoglossus occidentalis* was found in a timber shipment from the USA (Malumphy et al. 2008) indicating multiple introductions of this species into Europe. Ornamental trade and movement as stowaways with transport vehicles are the major pathways for alien Heteroptera (Rabitsch

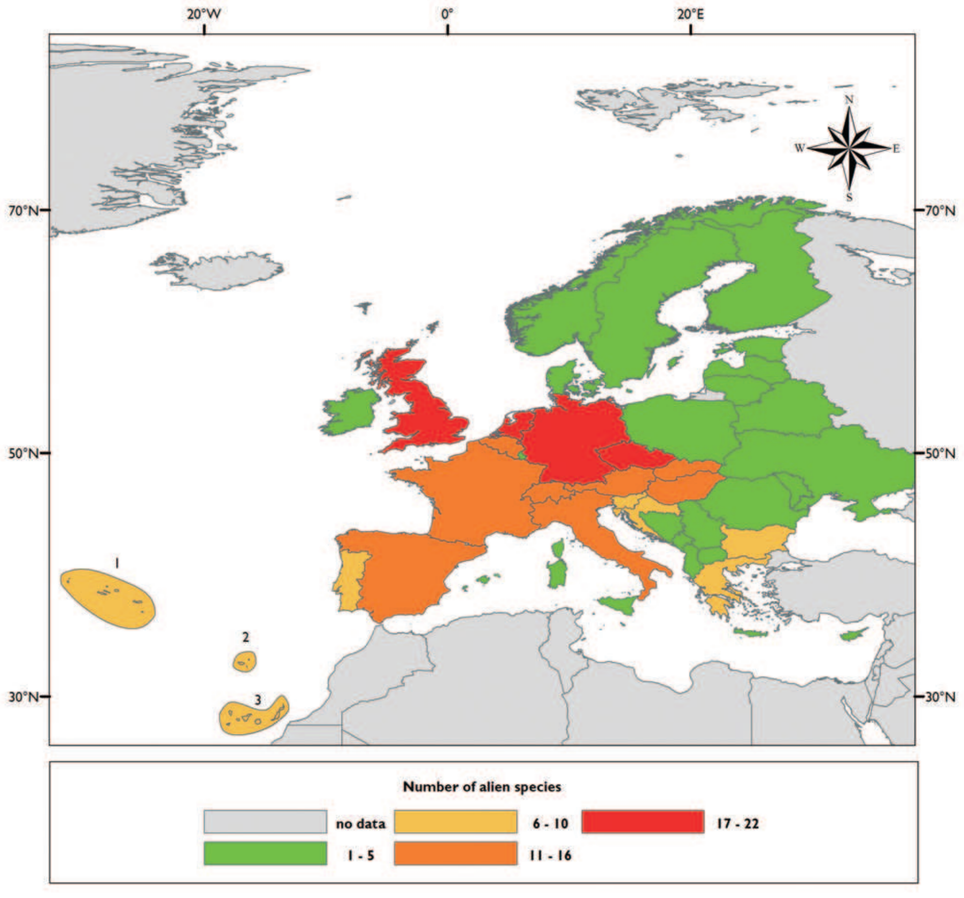

Figure 9.1.5. Numbers of established alien Heteroptera species per European country. Data rely on Tables 9.1.1 and 9.1.2. Aliens with doubtful status are included. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

2008), also confirmed by the interruption of introductions between 1925 and 1949 (Figure 9.1.4).

9.1.7 Ecosystems and habitats invaded by alien Heteroptera in Europe

Most alien Heteroptera colonize habitats under strong human influence, like agricultural, horticultural, and domestic habitats (51%) and parks and gardens (27%) (Figure 9.1.6). Some species prefer woodland including plantations of non-native forest trees. It is worth mentioning that *Leptoglossus occidentalis* has not only spread across Europe, but has also

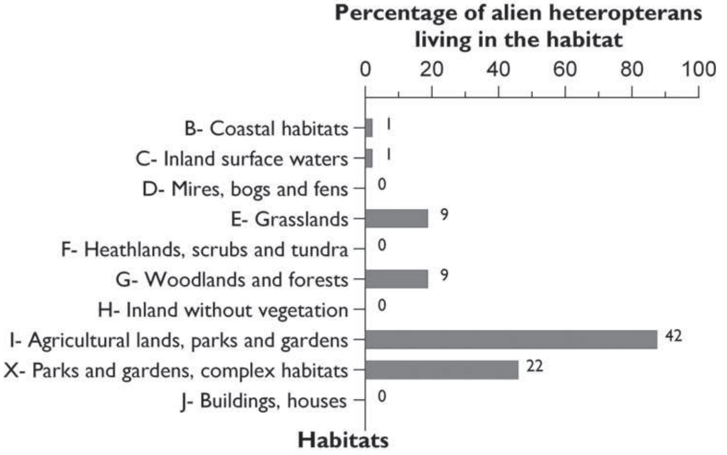

Figure 9.1.6. Main habitats colonized by alien Heteroptera species in Europe. The number above each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

expanded its occupied habitat: first records in most countries are indoors, from cities and harbours, but increasingly records in the field are observed at higher elevations. In France, *L. occidentalis* has twice been captured above 1000 m (Dusoulier et al. 2007) and in Austria (Styria) there is a documented record at 1500 m (Gepp, in litt.) (see factsheet 14.42).

9.1.8 Ecological and economic impact of alien Heteroptera in Europe

Impacts of alien Heteroptera in Europe are poorly investigated (Rabitsch 2008). A few species are considered pests in agriculture or forestry, e.g. *Nysius huttoni*, and *Leptoglossus occidentalis*, or on ornamental plants, e.g. *Corythucha ciliata* and *Stephanitis takeyai*, but damage is only locally reported in Europe to date. No data are available on any negative ecological impact on native species either due to predation, hybridization, competition or pathogen-transfer. However, as mentioned by Rabitsch (2008), no one has yet looked at such effects. It may be worth investigating intraguild competition within the juniper-feeding guild or the effects of *Trichocorixa verticalis* in aquatic communities.

9.1.9 Conclusion

It is essential to observe and document range changes of species. Clearly, the number of introduced Heteroptera will increase. Climate change and habitat modification will further promote establishment of additional species. Some introduced species, currently considered as not established, were excluded in this study, but may establish populations in the near

Figure 9.1.7. Adults of some alien Heteroptera species: **a** *Arocatus longiceps* (Credit: Wolfgang Rabitsch) **b** *Leptoglossus occidentalis* feeding on Scots pine (Credit: Alain Roques) **c** *Oxycarenus lavaterae* aggregating on trunk (Credit: Wolfgang Rabitsch) **d** *Oxycarenus lavaterae* detail (Credit: Wolfgang Rabitsch) **e** *Stephanitis takeyai* (Credit: Wolfgang Rabitsch) **f** *Tupiocoris rhododendri* (Credit: Ab Baas).

future; e.g., *Orius flagellum* Linnavuori, 1968 in the Netherlands (Aukema and Hermes 2009), *Xylocoris flavipes* (Reuter, 1875) in several European countries (Péricart 1972, 1996). Also, recent range changes of some continental European species need to be carefully reconsidered when new data become available as some of these may deserve alien status; e.g. Ødegaard & Endrestøl (2007), see Rabitsch (2008) for additional examples. Taking into account the increasing number of Heteroptera species introduced from North America and the often observed previous range increase in the native areas, it is recommended for Europe to keep an eye on range changes in North America, which may be an early indicator for possible future alien species to Europe. Finally, more research is needed for a better understanding of the ecological and economic effects of introduced Heteroptera.

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References

Aukema B (1996) *Stephanitis takeyai* on *Pieris japonica*. *Mededelingen van de Plantenziektenkundige Dienst* 179: 46–47.

Aukema B (1999) Heteroptera. In: Ackerman RA, van Halteren P, Jenniskens MJ (Eds) Annual Report Diagnostic Centre 1998. *Mededelingen van de Plantenziektenkundige Dienst* 200: 62–63.

Aukema B (2007) *Buchananiella continua* (Anthocoridae) in south Devon (VC3). *HetNews* 9: 12.

Aukema B (2008) De invasieve noord-amerikaanse wants *Leptoglossus occidentalis* bereikt ook Nederland (Heteroptera: Coreidae). *Nederlandse Faunistische Mededelingen* 29: 78–80.

Aukema B, Hermes D (2009) Nieuwe en interessante Nederlandse Wantsen III (Hemiptera: Heteroptera). *Nederlandse Faunistische Mededelingen* 31: 52–88.

Aukema B, Loomans A (2005) *Orius laevigatus* in the NL (Heteroptera, Anthocoridae). *Nederlandse Faunistische Mededelingen* 23: 125–127.

Aukema B, Rieger C (1995–2006). *Catalogue of the Heteroptera of the Palaearctic Region*. Vols 1–5. Amsterdam: The Netherlands Entomological Society. Vol. 1, 222 pp., Vol. 2, 361 pp., Vol. 3, 577 pp., Vol. 4, 346 pp., Vol. 5, 550 pp.

Aukema B, Bos F, Hermes D, Zeinstra P (2005a) Nieuwe en interessante nederlandse wantsen II, met een geactualiseerde naamlijst (Hemiptera: Heteroptera). *Nederlandse Faunistische Mededelingen* 23: 37–76.

Aukema B, Bruers JM, Viskens G (2005b) A New Zealand endemic *Nysius* established in the NL and BE (Heteroptera: Lygaeidae). *Belgian Journal of Entomology* 7: 37–43.

Aukema B, Bruers JM, Viskens GM (2007) Nieuwe en zeldzame Belgische wantsen II (Hemiptera: Heteroptera). *Bulletin van de Koninklijke Belgische Vereniging voor Entomologie* 143: 83–91.

Aukema B, Schwartz MD, Den Bieman K (2009a) *Tropidosteptes pacificus* (Van Duzee, 1921), another Nearctic mirid in Europe (Hemiptera: Heteroptera: Miridae: Mirinae). *Zootaxa* 2135: 65–68.

Aukema B, Bruers JM, Viskens GM (2009b) Nieuwe en zeldzame Belgische wantsen III (Hemiptera: Heteroptera). *Bulletin van de Koninklijke Belgische Vereniging voor Entomologie* 145: 25–31.

Barclay M (2004) The Green Vegetable Bug *Nezara viridula* (L., 1758) (Hem.: Pentatomidae), new to Britain. *Entomologist's Record* 116: 55–58.

Barclay M, Nau BS (2003) A second species of Tamarisk bug in Britain, *Tuponia brevirostris* Reuter, and the current status of *T. mixticolor* (A. Costa) (Hem., Miridae). *Entomologist's Monthly Magazine* 139: 176–177.

Benedek P, Jászai,VE (1968) On some species of the genus *Tuponia* Reuter, 1875 (Heteroptera: Miridae, Phylinae). *Acta Zoologica Academiae Scientiarum Hungaricae* 14: 7–13.

Bernardinelli I, Zandigiacomo P (2001) *Leptoglossus occidentalis* Heidemann (Heteroptera, Coreidae): a conifer seed bug recently found in northern ItalyT. *Journal of Forestry Science* 47: 56–58.

Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (2005) *A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Angra do Heroísmo: Universidade dos Açores. 318 pp.

Bruers J, Viskens G (1999) *Stephanitis oberti* (Kolenati, 1856) Belg. n. sp. *Entomo-Info* 10: 11.

Bryja J, Kment P (2002) New and interesting records of plant bugs (Heteroptera: Miridae) from the Czech and SKs. *Klapalekiana* 38: 1–10.

Carapezza A (1980) *Saldula sardoa* Fil., specie propria e *Pentacora sphacelata* (Uhler) in Sardegna. *Bollettino della Societá Sarda di Scienze Naturali* 20: 49–54.

Chérot F, Ribes J, Gorczyca J (2006) A new *Fulvius* species from Azores Islands (Heteroptera: Miridae: Cylapinae). *Zootaxa* 1153: 63–68.

Cuming N (2008) New to British Isles: *Nysius huttoni* White, 1878. *HetNews* 11: 10.

De Clercq P (2000) Predaceous Stinkbugs (Pentatomidae: Asopinae). In Schaefer C, Panizzi A (Eds) *Heteroptera of Economic Importance*. Boca Raton, Florida: CRC Press, 737–789.

Dioli P, Forini IG, Moretti M, Salvetti M (2007) Note sulla distribuzione di *Corythucha arcuata* (Insecta, Heteroptera, Tingidae) in Cantone Ticino (Svizzera), Valtellina e alto Lario (Lombardia, Italia). *Il Naturalista Valtellinese* 18: 59–68.

Dolling WR (1972) A new species of *Dicyphus* Fieber (Hem., Miridae) from southern England. *Entomologist's Monthly Magazine* 107: 244–245.

Dusoulier F, Lupoli R, Aberlenc HP, Streito JC (2007) L'invasion orientale de *Leptoglossus occidentalis* en France: bilan de son extension biogéographique en 2007 (Hemiptera Coreidae). *L'Entomologiste* 63: 303–308.

Essl F, Rabitsch W (2002) *Neobiota in Österreich*. Wien: Umweltbundesamt, 432 pp.

Forster B, Giacalone I, Moretti M, Dioli P, Wermelinger B (2005) Die amerikanische Eichennetzwanze *Corythucha arcuata* (Say) (Heteroptera, Tingidae) hat die Südschweiz erreicht. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 78: 317–323.

Frieß T, Rabitsch W (2009) *Checkliste und Rote Liste der Wanzen Kärntens (Insecta: Heteroptera)*. Carinthia II 199/119, in press.

Geiter O, Homma S, Kinzelbach R (2002) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltbundesamt 25: 1–173.

Gessé F, Ribes J, Goula M (2009) *Belonochilus numenius*, the sycamore seed bug, new record for the Iberian fauna. *Bulletin of Insectology* 62: 121–123.

Göricke P (2008) Zum Auftreten von *Arocatus longiceps* Stål, 1872 (Lygaeidae) und Vorkommen von *Cephalocteus scarabaeoides* (Fabricius, 1803) (Cydnidae) an der Atlantikküste Portugal. *Heteropteron* 28: 27.

Halstead AJ, Malumphy CP (2003) Outbreak in Britain of *Stephanitis takeyai* Drake & Mao (Hemiptera: Tingidae), a pest of *Pieris japonica*. *The British Journal of Entomology and Natural History* 16: 3–6.

Heiss E, Péricart J (2007) *Hemiptères Aradidae Piesmatidae et Dipsocoromorphes euro-méditerranéens. Faune de France 91.* Paris: Fédération Française des Sociétés de Sciences Naturelles. 509 pp.

Henry TJ (1997) Phylogenetic analysis of family groups within the infraorder Pentatomomorpha (Hemiptera: Heteroptera), with emphasis on the Lygaeoidea. *Annals of the Entomological Society of America* 90: 275–301.

Henry TJ (2009) *Biodiversity of Heteroptera*. In Foottit RG, Adler PH (Eds) Insect Biodiversity: Science and Society. Chichester, UK: Wiley-Blackwell, 223–263.

Hoffmann HJ (2003) Neozoen bei Wanzen. *Heteropteron* 16: 25–28.

Hoffmann HJ (2008) On Plane trees, not only *Arocatus longiceps* (Lygaeidae) but also *Arocatus roeselii*? *HetNews* 12: 4–6.

Hollier J, Matocq A (2004) *Dicyphus escalerae* Lindberg, 1934 (Hemiptera: Miridae), a plantbug species new for Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 77: 333–335.

Hradil K (2008) *Leptoglossus occidentalis* (Heteroptera: Coreidae) a new alien species in Montenegro. *Acta entomologica serbica* 13: 77–79.

Hradil K, Kapitola P, Jindra Z, Kment P (2002) Faunistic records from the Czech Republic – 146. *Klapalekiana* 38: 113–114.

Hradil K, Kment P, Bryja J, Roháčová M, Baňař P, Ďurčová K (2008) New and interesting records of true bugs (Heteroptera) from the Czech Republic and Slovakia IV. *Klapalekiana* 44: 165–206.

Ishikawa T, Kikuhara Y (2009) *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae), a presumable recent invader to Japan. *Japanese Journal of Entomology* 12: 115–116.

Jindra Z, Kment P (2006) Faunistic records from the Czech Republic – 212. *Klapalekiana* 42: 333–334.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Delémont: CABI Bioscience Switzerland, 131–212.

Kerzhner IM, Josifov M (1999) *Miridae Hahn, 1831*. In: Aukema B, Rieger C (Eds) Catalogue of the Heteroptera of the Palaearctic Region. Vol. 3. The Netherlands Entomological Society, Amsterdam, 577 pp.

Kirby P (1999) *Buchananiella continua* (B. White) (Hemiptera: Anthocoridae) established in Britain. *British Journal of Entomology and Natural History* 12: 221–223.

Kirby P, Stewart A, Wilson M (2001) True bugs, leaf- and planthoppers, and their allies. In: Hawksworth, DL (Ed) *The changing wildlife of Great Britain and Ireland*. London: Taylor & Francis, 262–299.

Kirby P, Bantock T, Nau B (2009) *Dicyphus escalerae* Lindberg, 1934. *HetNews* 13: 7–8.

Kivan M (2004) Some observations on *Perillus bioculatus* (F.) (Heteroptera: Pentatomidae) a new record for the entomofauna of Turkey. *Turkish Journal of Entomology* 28: 95–98.

Kment P (2006a) A contribution to the faunistics of aquatic and semiaquatic bugs (Heteroptera: Nepomorpha, Gerromorpha) in Portugal, with the review of biology of the Nearctic corixid *Trichocorixa verticalis* (Fieber, 1851). *Boletín Sociedad Entomológica Aragonesa* 38: 359–361.

Kment P (2006b) Heteroptera – Plostice. In: Mlíkovský J, Stýblo P (Eds) *Nepuvodní druhy fauny a flory Ceske Republiky.* Praha: Èeský svaz ochráncù pøírody, 255–266.

Kment P (2007) First record of the alien lace bug *Stephanitis pyrioides* in Greece and note on *Corythucha ciliata* in Portugal (Heteroptera: Tingidae). *Linzer Biologische Beiträge* 39: 421–429.

Kment P (2009) *Oxycarenus lavaterae*, an expansive species new to Romania (Hemiptera: Heteroptera: Oxycarenidae). *Acta Musei Moraviae, Scientiae biologicae* 94: 23–25. 55. Kment P, Baňar P (2008) Additional records of the invasive nearctic bug *Leptoglossus occidentalis* (Heteroptera: Coreidae) in Croatia. *Natura Croatica* 17: 141–147.

Kment P, Bryja J, Hradil K, Jindra Z (2005) New and interesting records of true bugs (Heteroptera) from the Czech Republic and Slovakia III. *Klapalekiana* 41: 157–213.

Kment P, Vahala O, Hradil K (2006) First records of *Oxycarenus lavaterae* (Heteroptera: Oxycarenidae) from the CZ, with review of its distribution and biology. *Klapalekiana* 42: 97–127.

Kondorosy E (1997) Other species of Heteroptera, new for fauna of Hungary. *Folia Entomologica Hungarica* 58: 249–251.

Kondorosy E (2005) New true bug species in the Hungarian fauna. *Folia Entomologica Hungarica* 66: 17–22.

Kowarik I (1995) Time lags in biological invasions with regard to the success and failure of alien species. In: Pyšek P, Prach K, Rejmánek M, Wade PM (Eds) *Plant invasions – general aspects and special problems*. Amsterdam: SPB Academic Publishers, 15–38.

Lattin JD (1999) Bionomics of the Anthocoridae. *Annual Review of Entomology* 44: 207–231.

Lindskog P, Viklund B (2000) On *Deraeocoris lutescens* (Schilling) and *Pinalitus atomarius* (Meyer-Dür) in SE (Heteroptera: Miridae). *Entomologica Fennica* 11: 231–238.

Lis JA, Lis B, Gubernator J (2008) Will the invasive western conifer seed bug *Leptoglossus occidentalis* Heidemann (Hemiptera: Heteroptera: Coreidae) seize all of Europe? *Zootaxa* 1740: 66–68.

Malumphy C, Reid S (2007) Non-native Heteroptera associated with imported plant material in England during 2006 & 2007. *HetNews* 10: 2–3.

Malumphy C, Reid S (2008) First interception of *Natalicola pallidus* (Westwood) (Tessaratomidae) in the UK. *HetNews* 12: 9.

Malumphy C, Botting J, Bantock T, Reid S (2008) Influx of *Leptoglossus occidentalis* Heidemann (Coreidae) in England. *HetNews* 12: 7–9.

Matocq A (2008) Présence en France et en Corse d'un Hétéroptère néarctique, *Belonochilus numenius* (Say, 1831) (Hemiptera, Lygaeidae, Orsillinae). *Bulletin de la Société entomologique de France* 113: 533–534.

Millán A, Hernando C, Aguileira P, Castro A, Ribera I (2005) Los coleópteros acuáticos y semiacuáticos de Donana: Reconocimiento de su biodiversidad y prioridades de conservación. *Boletín Sociedad Entomológica Aragonesa* 36: 157–164.

Nau BS (1980) *Tuponia carayoni* Wagner (Hem., Miridae) new to Britain. *Entomologist's Monthly Magazine* 116: 83–84.

Nau BS (2007) „Unknown" orthotyline on Wellingtonia in Oxford. *HetNews* 9: 9.

Nau BS, Straw N (2007) *Arocatus roeselii* established in Britain? *HetNews* 9: 8.

Ødegaard F, Endrestøl A. (2007) Establishment and range expansion of some new Heteroptera (Hemiptera) in Norway. *Norwegian Journal of Entomology* 54: 117–124.

Péricart J (1965) Contribution à la faunistique de la Corse: hétéroptères Miridae et Anthocoridae. *Bulletin Mensuel de la Société Linnéenne de Lyon* 34: 377–384.

Péricart J (1972) *Hémiptères Anthocoridae, Cimicidae, Microphysidae de l'Ouest Paléarctique*. Faune de l'Europe et du bassin méditerranéen. Paris: Masson. 403 pp.

Péricart J (1996) Anthocoridae Fieber, 1836. In: Aukema B, Rieger C (Eds) *Catalogue of the Heteroptera of the Palaearctic Region. Vol. 2.* Amsterdam: The Netherlands Entomological Society, 108–140.

Péricart J, Stehlík JL (1998) *Amphiareus obscuriceps* (Popp.) in the Czech Republic and in the Balkan Peninsula (Heteroptera: Anthocoridae). *Acta Musei Moraviae, Scientiae biologicae* 83: 217–218.

Protić L (2008) *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae) in Serbia. *Acta entomologica serbica* 13: 81–84.

Putshkov PV, Putshkov VG (1996) Reduviidae Latreille, 1807. In Aukema B, Rieger C (Eds) *Catalogue of the Heteroptera of the Palaearctic Region. Vol. 2.* Amsterdam: The Netherlands Entomological Society, 148–266.

Rabitsch W (2002) Die Arten der Gattung Tuponia (Heteroptera: Miridae) im östlichen Österreich. *Beiträge zur Entomofaunistik* 3: 97–102.

Rabitsch W (2008) Alien True Bugs of Europe (Insecta: Hemiptera: Heteroptera). *Zootaxa* 1827: 1–44.

Rabitsch W, Adlbauer K (2001) Erstnachweis und bekannte Verbreitung von *Oxycarenus lavaterae* (Fabricius, 1787) in Österreich (Heteroptera: Lygaeidae). *Beiträge zur Entomofaunistik* 2: 49–54.

Rédei D, Torma A (2003) Occurrence of the Southern Green Stink Bug, *Nezara viridula* (Heteroptera: Pentatomidae) in Hungary. *Acta Phytopathologica et Entomologica Hungarica* 38: 365–367.

Ribes J, Pagola-Carte S (2008) *Arocatus longiceps* Stal, 1872, primera cita para la península Ibérica (Hemiptera: Heteroptera: Lygaeidae). *Boletín Sociedad Entomológica Aragonesa* 42: 353–354.

Rodríguez-Pérez H, Florencio M, Gómez-Rodríguez C, Green AJ, Díaz-Paniagua C, Serrano L (2009) Monitoring the invasion of the aquatic bug *Trichocorixa verticalis verticalis* (Hemiptera: Corixidae) in the wetlands of Doñana National Park (SW Spain). *Hydrobiologia* 634: 209–217.

Roques A, Auger-Rozenberg MA (2006) Tentative analysis of the interceptions of non-indigenous organisms in Europe during 1995–2004. *EPPO Bulletin* 36: 490–496.

Roques A, Rabitsch W, Lopez-Vaamonde C, Nentwig W, Kenis M (2008) Alien terrestrial invertebrates of Europe. In: DAISIE (Ed) *The Handbook of Alien Species in Europe*. Dordrecht: Springer, 63–79.

Ruicănescu A (2009) *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae) in România. In Rákosy L, Momeu L (Eds) *Neobiota din Romania*. Cluj: Presa Universitară Clujeană, 153–154.

Sala J, Boix D (2005) Presence of the nearctic water boatman *Trichocorixa verticalis verticalis* (Fieber, 1851) (Heteroptera: Corixidae) in the Algarve region (South Portugal). *Graellsia* 61: 31–36.

Schaefer CW, Panizzi AR (2000) *Heteroptera of Economic Importance*. Boca Raton, Florida: CRC Press. 828 pp.

Schuh RT, Slater JA (1995) *True bugs of the World (Hemiptera: Heteroptera)*. Ithaca: Cornell University Press. 336 pp.

Šefrová H, Laštùvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Servadei A (1966) Un Tingide nearctico comparso in Italia (*Corythucha ciliata* Say). *Bollettino della Societa Entomologica Italiana* 96: 94–96.

Simon H (1995) Nachweis von *Dicyphus escalerai* <sic> Lindberg, 1934 (Heteroptera: Miridae) in Mitteleuropa. *Fauna und Flora Rheinland-Pfalz* 8: 53–63.

Simon H (2007) 1. Nachtrag zum Verzeichnis der Wanzen in Rheinland-Pfalz (Insecta: Heteroptera). *Fauna und Flora Rheinland-Pfalz* 11: 109–135.

Simov N (2008) Western conifer seed bug *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae) already in Bulgaria. *Historia naturalis Bulgarica* 19: 179–180.

Simov N, Pencheva A (2007) *Stephanitis rhododendri* Horváth, 1905 (Heteroptera: Tingidae) – a new American pest on rhododendrons in Bulgaria. *Plant Science (Sofia)* 43: 483–485.

Smit JT, Reemer M, Aukema B (2007) Een invasie van de nieuw-zeelandse tarwewants *Nysius huttoni* in Nederland (Heteroptera: Lygaeidae). *Nederlandse Faunistische Mededelingen* 27: 51–70.

Stehlík JL (1997) *Corythucha ciliata* (Say), a pest of plane trees, now also in the Czech Republic (Tingidae, Het.). *Acta Musei Moraviae, Scientiae Natural*es 81: 299–306.

Streito JC (2006) Note sur quelques espèces envahissantes de Tingidae: *Corythucha ciliata* (Say, 1832), *Stephanitis pyrioides* (Scott, 1874) et *Stephanitis takeyai* Drake & Maa, 1955 (Hemiptera Tingidae). *L'Entomologiste* 62: 31–36.

Sweet MH (2000) Seed and Chinch Bugs (Lygaeoidea). In: Schaefer CW, Panizzi AR (Eds) *Heteroptera of Economic Importance*. Boca Raton, Florida: CRC Press, pp. 143–264.

Takács S, Bottomley H, Andreller I, Zaradnik T, Schwarz J, Bennett R, Strong W, Gries G (2009) Infrared radiation from hot cones on cool conifers attracts seed-feeding insects. *Proceedings Royal Society London B* 276: 649–655.

Velimirovic V, Durovic Z, Raicevic M (1992) Bug *Oxycarenus lavaterae* Fabricius (Lygaeidae, Heteroptera) new pest on lindens in southern part of Montenegro. *Zastita Bilja* 43: 69–72.

Voigt K (1977) Bemerkenswerte Wanzenfunde aus Baden-Württemberg, mit einem Erstnachweis für Deutschland. *Beiträge zur naturkundlichen Forschung in Südwestdeutschland* 36: 153–158.

Wermelinger B, Wyniger D, Forster B (2005) Massenauftreten und erster Nachweis von *Oxycarenus lavaterae* (F.) (Heteroptera, Lygaeidae) auf der Schweizer Alpennordseite. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 78: 311–316.

Wermelinger B, Wyniger D, Forster B (2008) First records of an invasive bug in Europe: *Halyomorpha halys* Stål (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees? *Mitteilungen der Schweizer Entomologischen Gesellschaft* 81: 1–8.

Werner DJ (2005) *Nezara viridula* (Linnaeus, 1758) in Köln und in Deutschland (Heteroptera, Pentatomidae). *Heteropteron* 21: 29–31.

Wheeler AG (2001) *Biology of the Plant Bugs (Hemiptera: Miridae). Pests, Predators, Opportunists*. Ithaca: Cornell University Press. 506 pp.

Table 9.1.1. List and main characteristics of Heteroptera species alien *to* Europe. Status: **A** Alien *to* Europe **C** cryptogenic species. For details see Rabitsch (2008). ? = occurrence doubtful, * = probably not established. New data since Rabitsch (2008) are given in bold. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update May 2009.

Family *Species*	**Status**	**Feeding Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**Refs**
Anthocoridae								
Amphiareus obscuriceps (Poppius, 1909)	A	Zoo-phagous	East Palaearctic	1987, BG	AT, BE, BG, BY, CZ, DE, EE, FI, HU, IT, NL, SK	E, I	–	Aukema (2007), Aukema et al. (2005a), Hradil et al. (2008), Péricart and Stehlík (1998)
***Amphiareus constrictus* (Stål, 1860)**	C	Zoo-phagous	Cosmopolitan	2007, NL	**NL**	E	–	Aukema and Hermes (2009)
Buchananiella continua (White, 1880)	C	Zoo-phagous	Pantropical	1880, PT-MAD	**BE,** ES, ES-CAN, FR, GB, IT, **NL,** PT, PT-AZO, PT-MAD	I, X	–	Aukema and Hermes (2009), Aukema et al. (2009b), Kirby (1999)
Lyctocoris campestris (Fabricius, 1794)	C	Zoo-phagous	West Palaearctic? Cosmopolitan	?	AL, AT, BA, BE, BG, BY, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IE, IT, IT-SAR, IT-SIC, LT, LU, LV, MD, ME, MK, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RS, SE, SI, SK, UA	I	–	Péricart (1972)
Coreidae								
Leptoglossus occidentalis Heidemann, 1910	A	Phyto-phagous	North America	1999, IT	AT, BE, **BG,** CH, CZ, DE, ES, FR, GB, **GR** , HR, HU, IT, **ME, NL,** PL, **RO,** RS, SI, SK	G, I, X	Pinaceae (*Pinus*, *Pseudotsuga*, *Picea*, *Abies*), Cupressaceae (*Libocedrus*)	Aukema (2008), Bernardinelli and Zandigiacomo (2001), Dusoulier et al. (2007), Hradil (2008), Kment et al. (2005), Malumphy et al. (2008), Protić (2008), Ruicănescu (2009)

Family *Species*	Status	Feeding Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	Refs
Corixidae								
Trichocorixa verticalis (Fieber, 1851)	A	Omni-vorous	North America	1997, PT	ES, PT	C	–	Kment (2006a), Sala and Boix (2005)
Lygaeidae								
Nysius huttoni F.B.White, 1878	A	Phyto-phagous	New Zealand	2002, NL	BE, FR, **GB,** NL	I	Poaceae, Brassicaceae and others (polyphagous)	Aukema et al. (2005b), Cuming (2008)
***Belonochilus numenius* (Say, 1831)**	A	Phyto-phagous	North America	2008, FR	**ES, FR, FR-COR**	I	Platanaceae (*Platanus*)	Gessé et al. (2009), Matocq (2008)
Miridae								
***Fulvius borgesi* Chérot, J. Ribes & Gorczyca, 2006**	A	Zoophyto-phagous?	South America	2003, PT-AZO	**PT-AZO**	I	–	Chérot et al. (2006)
Nesidiocoris tenuis (Reuter, 1895)	C	Zoophyto-phagous	Pantropical	?	CY, ES, ES-CAN, FR, GR, GR-CRE, IT, MT, PT-MAD	I	–	Kerzhner and Josifov (1999)
Taylorilygus apicalis (Fieber, 1861)	C	Phyto-phagous	Pantropical	?	AL, BA, BG, CY, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, SI, UA	I	Asteraceae and others (polyphagous)	Kerzhner and Josifov (1999)
***Tropidosteptes pacificus* Van Duzee, 1921**	A	Phyto-phagous	North America	2007, NL	**NL**	G	Oleaceae (*Fraxinus excelsior*)	Aukema et al. (2009a)
Tupiocoris rhododendri (Dolling, 1972)	A	Zoo-phagous	North America	1971, GB	BE, DE, GB, NL	I, X	Ericaceae (*Rhodo-dendron*)	Aukema et al. (2005a), Aukema et al. (2007), Dolling (1972)

Family *Species*	**Status**	**Feeding Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**Refs**
Pentatomidae								
Halyomorpha halys (Stål, 1855)	A	Phyto-phagous	East Asia	2007, CH	CH	I, X	fruit trees and ornamentals (polyphagous)	Wermelinger et al. (2008)
Perillus bioculatus (Fabricius, 1775)	A	Zoo-phagous	North America	1992, TU	GR, TU	G, I	–	Kivan (2004)
Reduviidae								
Empicoris rubromaculatus (Blackburn, 1889)	C	Zoo-phagous	Pantropical	?	**BE,** ES, ES-CAN, FR, FR-COR, **GR,** HR, IT, PT, PT-AZO, PT-MAD	I	–	Aukema et al. (2009b)
Ploiaria chilensis (Philippi, 1862)	C	Zoo-phagous	Pantropical	?	?CY, ES, ES-CAN, ?IT, PT-AZO, PT-MAD	I	–	Putshkov and Putshkov (1996)
Saldidae								
Pentacora sphacelata (Uhler, 1877)	A	Zoo-phagous	North America	1953, ES	ES, IT, PT	B	–	Carapezza (1980)
Tingidae								
Corythucha arcuata (Say, 1832)	A	Phyto-phagous	North America	2000, IT	CH, IT	G	Fagaceae (*Quercus*, *Castanea*)	Dioli et al. (2007), Forster et al. (2005)
Corythucha ciliata (Say, 1832)	A	Phyto-phagous	North America	1964, IT	AT, BE, BG, CH, CZ, DE, ES, FR, GB, GR, HR, HU, IT, ME, **NL,** PT, RS, SK, SI	I, X	Platanaceae (*Platanus*)	Aukema and Hermes (2009), Kment (2007), Servadei (1966), Stehlík (1997), Streito (2006)
Stephanitis pyrioides (Scott, 1874)	A	Phyto-phagous	Japan	1904, NL	CH, *FR, GR, IT, NL	I, X	Ericaceae (*Rhodo-dendron*)	Kment (2007), Streito (2006)
Stephanitis rhododendri Horváth, 1905	A	Phyto-phagous	North America	<1900, NL	*BE, BG, CH, CZ, DE, DK, *FI (J100), *FR, GB, NL, *PL, SE	I, X	Ericaceae (*Rhodo-dendron*)	Halstead and Malumphy (2003), Jindra and Kment (2006), Simov and Pencheva (2007)
Stephanitis takeyai Drake & Maa, 1955	A	Phyto-phagous	Japan	1994, NL	BE, **CZ,** DE, FR, GB, IT, NL, PL	I, X	Ericaceae (*Pieris*, *Rhododendron*)	Aukema (1996), Halstead and Malumphy (2003), Ishikawa and Kikuhara (2009), Streito (2006)

Table 9.1.2. List and characteristics of the Heteroptera species alien *in* Europe. For details see Rabitsch (2008). ?N = Alien status doubtful (species could be native), ? = occurrence doubtful, * = probably not established. New data since Rabitsch (2008) are given in bold. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update May 2009.

Family *Species*	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Anthocoridae							
Anthocoris butleri Le Quesne, 1954	Zoo-phagous	Southwest Europe	1962, CZ	AT, BE, CH (?N), CZ, DE (?N), IE, LU, NL, SE (Gotland), SK	I, X	Buxaceae (*Buxus*)	Kment et al. (2006)
Anthocoris sarothamni Douglas & Scott, 1865	Zoo-phagous	West Mediterranean	1953, CZ	*AT, CZ	I, X	Fabaceae (*Cytisus*)	Kment (2006b)
***Orius laevigatus* (Fieber, 1860)**	Zoo-phagous	Southwest Europe	2005, NL	**NL**	I	–	Aukema and Loomans (2005)
Lygaeidae							
Arocatus longiceps Stål, 1872	Phyto-phagous	East Mediterranean	1990, HU	AT, BE, CH, CZ, DE, **ES,** FR (N?), **GB,** HU, NL, **PT,** SI (?N), SK	I, X	Platanaceae (*Platanus*)	Göricke (2008), Kondorosy (1997), Nau and Straw (2007), Ribes and Pagola-Carte (2008)
Orsillus depressus (Mulsant & Rey, 1852)	Phyto-phagous	Mediterranean	1971, DE	AT (?N), BE, CZ, DE, *FI, GB, HU (?N), LU, NL, SK	E, I, X	Cupressaceae	Hradil et al. (2002), Voigt (1977)
Oxycarenus lavaterae (Fabricius, 1787)	Phyto-phagous	West Mediterranean	1985, ME	AT, BG, CH (north), CZ, DE, *FI, FR(north), HU, ME, ***NL**, **RO,** RS, **SI,** SK	G, I, X	Malvaceae (*Tilia*)	Hradil et al. (2008), Kment (2009), Kondorosy (1997), Rabitsch and Adlbauer (2001), Velimirovic et al. (1992), Wermelinger et al. (2005)
Miridae							
Closterotomus trivialis (A. Costa, 1853)	Phyto-phagous	Mediterranean	1998, NL	NL	I	Weeds, olive trees, Citrus (polyphagous)	Aukema (1999), Aukema and Hermes (2009)
***Deraeocoris lutescens* (Schilling, 1837)**	Zoo-phagous	West Palaearctic	1990, NO	**NO, SE**	I, X	Malvaceae (*Tilia*)	Lindskog and Viklund (2000), Ødegaard and Endrestøl (2007)

Family *Species*	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Deraeocoris flavilinea (A. Costa, 1862)	Zoo-phagous	Mediterranean	1961, FR-COR	AL, AT, BE, CH, CZ, DE, FR (Alsace), FR-COR, GB, LU, MT, NL, SE, SI	I, X	Many trees and shrubs	Kment et al. (2006), Péricart (1965)
Dichrooscytus gustavi Josifov, 1981	Phyto-phagous	European – Cryptogenic	1934, DE	AT, BE, CZ, DE, FI, FR, GB, HU, ?IT, LU, NL, SK	I	Cupressaceae	Bryja and Kment (2002), Hradil et al. (2008)
Dicyphus escalerae Lindberg, 1934	Phyto-phagous	West Mediterranean	1994, DE	CH, DE, **GB**	I	Veronicaceae (*Antirrhinum majus*)	Hollier and Matocq (2004), Kirby et al. (2009), Servadei (1966)
Macrolophus glaucescens Fieber, 1858	Zoo-phagous	Mediterranean	<1858, CZ	CZ	E	Asteraceae (*Echinops*)	Kment (2006b)
Orthotylus adenocarpi (Perris, 1857)	Zoophyto-phagous	West Mediterranean	<1892?, CZ	CZ (?N)	E, G, I	Fabaceae (*Cytisus*)	Kment (2006b)
Orthotylus caprai Wagner, 1955	Zoophyto-phagous	Mediterranean	2006, GB	DE, GB	I	Cupressaceae	Nau (2007), Simon (2007)
Orthotylus concolor (Kirschbaum, 1856)	Zoophyto-phagous	West Mediterranean	<1892?, CZ	***AT,** CZ (?N)	E, G, I	Fabaceae (*Cytisus*)	Frieß and Rabitsch (2009), Kment (2006b)
Orthotylus virescens (Douglas & Scott, 1865)	Zoophyto-phagous	West Mediterranean	2003, HU	CZ (?N), HU	E, G, I	Fabaceae (*Cytisus*)	Kment (2006b), Kondorosy (2005)
Tuponia brevirostris Reuter, 1883	Phyto-phagous	West Mediterranean	2001, GB	DE, GB, **GR (?N)**, HR	I, X	Tamaricaceae (*Tamarix*)	Barclay and Nau (2003), Simon (2007)
Tuponia elegans (Jakovlev, 1867)	Phyto-phagous	Central Asia	1964, HU	AT, CZ, HU, SK	I, X	Tamaricaceae (*Tamarix*)	Benedek and Jászai (1968), Bryja and Kment (2002), Hradil et al. (2008), Rabitsch (2002)
Tuponia hippophaes (Fieber, 1861)	Phyto-phagous	Mediterranean	<1982, SK	CZ, BE, SK	I, X	Tamaricaceae (*Tamarix*)	Bryja and Kment (2002), Hradil et al. (2008)
Tuponia macedonica Wagner, 1957	Phyto-phagous	East Mediterranean	2003, SK	SK	I, X	Tamaricaceae (*Tamarix*)	Hradil et al. (2008)

Family *Species*	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tuponia mixticolor (A. Costa, 1862)	Phyto-phagous	Mediterranean-Central Asia	1979, GB	DE, GB, SI (?N)	I, X	Tamaricaceae (*Tamarix*)	Nau (1980), Simon (2007)
Pentatomidae							
Nezara viridula (Linnaeus, 1758)	Phyto-phagous	Mediterranean and/or Africa	1979, DE	*AT, *BE, BG (?N), CH (north), DE, *FI, GB, HU, *UA	I, X	Fabaceae, cultivated and uncultivated plants (polyphagous)	Barclay (2004), Rédei and Torma (2003), Wheeler (2001)
Tingidae							
Dictyonota fuliginosa A. Costa, 1853	Phyto-phagous	West Mediterranean	1954, CZ	CZ	E, G, I	Fabaceae (*Cytisus*)	Kment (2006b)
Elasmotropis testacea (Herrich-Schäffer, 1830)	Phyto-phagous	Palaearctic	<1844, CZ	CZ, DE (?N), ?PL	E, I	Asteraceae (*Echinops*)	Kment (2006b)
Stephanitis oberti (Kolenati, 1857)	Phyto-phagous	North Palaearctic	<1906?, DE	*AT, BE (?N), CZ (?N), DE (?N), NL (?N)	I, X	Ericaceae (*Rhodo-dendron*, *Vaccinium*)	Bruers and Viskens (1999)

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Aphids (Hemiptera, Aphididae) Chapter 9.2

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Abstract
Our study aimed at providing a comprehensive list of Aphididae alien *to* Europe. A total of 98 species originating from other continents have established so far in Europe, to which we add 4 cosmopolitan species of uncertain origin (cryptogenic). The 102 alien species of Aphididae established in Europe belong to 12 different subfamilies, five of them contributing by more than 5 species to the alien fauna. Most alien aphids originate from temperate regions of the world. There was no significant variation in the geographic origin of the alien aphids over time. The average introduction rate was 0.5 species per year since 1800. The mean number of newly recorded species per year decreased since 2000 but this pattern may change in the following years.

Keywords
alien, Hemiptera, Aphid, Aphididae, Europe

9.2.1. Introduction

About 4700 species of Aphididae have been described worldwide (Remaudière and Remaudière 1997). About one third of these species are present in Europe. As for many other taxonomic groups, very few checklists of alien Aphididae have been available for Europe until recently. In 2002, Geiter et al. (2002) published a list of 131 species considered non-indigenous in Germany and Nobanis (2005) listed 34 species of non-native Aphididae in its geographic area in 2005. Lampel and Gonseth (2005) listed 37 species alien to Switzerland in 2005 whilst Rabitsch and Essl (2006) listed 40 alien aphid species from Austria in 2006. The differences in the number of species considered non-indigenous clearly reflect differences in the composition of the fauna of each country, but also reflect differences in the definition of 'alien'. Lampel and Gonseth (2005) considered only species of non-European origin whereas Geiter et al. (2002) included all species considered non-native to Germany.

The goal of this work is to provide a first comprehensive list of Aphididae alien *to* Europe. Aphid species originating from one European country and introduced into another, i.e. species alien *in* Europe such as *Diuraphis noxia* (Kurdjumov, 1913) and *Brachycorynella asparagi* (Mordvilko, 1929), will not be considered in this work. These species may have an invasive status in the area where they were introduced but it appeared difficult to disentangle human- mediated introductions from natural expansion.

To define the species present in Europe, we used the list of European Aphididae elaborated by Nieto Nafria for Fauna Europaea (Nieto Nafria et al. 2007). We compiled information about each species from published sources and experts to define their origin, i.e. European vs non-European. Among the references consulted, the lists cited above and the three comprehensive books by Blackman & Eastop (Blackman and Eastop 1994, 2000, 2006) proved to be particularly useful. Once a first list of alien aphids had been defined, we sought additional information, such as the date of first occurrence in Europe. June 2008 was the cut-off date for our literature survey. All the information collected for the 102 species considered is provided in Table 9.2.1.

9.2.2. Taxonomy of alien species

The delineation of the taxa included under the family name Aphididae has varied over the last 50 years. Here, we use Aphididae *sensu* Eastop and Hille Ris Lambers (1976) and Remaudière and Remaudière (1997). Therefore, we did not consider Adelgidae and Phylloxeridae in this chapter. Taxonomy and nomenclature are as described by Remaudière and Remaudière (1997), Nieto Nafria et al. (1998), Quednau (1999, 2003), and Eastop and Blackman (2005). Some of the names cited in published studies could not be clearly attributed to a currently valid taxon and were therefore excluded.

A total of 98 species present in Europe but originating from another continent have been listed to date, to which we can add four cosmopolitan species of uncertain origin (cryptogenic) (Table 9.2.1). For comparison, the European aphid fauna currently includes 1,373 species (Nieto Nafria et al. 2007), meaning that 7.4 % of the European aphid fauna is of alien origin.

The 102 alien species of Aphididae established in Europe belong to 12 different subfamilies, most of which are already represented among the native entomofauna (Figure 9.2.1). However, three subfamilies (Greenideinae, Lizerinae and Neophyllaphidinae) were not known in Europe before introductions. Each of these three subfamilies is represented by a single species. *Greenidea ficicola* is a member of the Greenideinae subfamily widespread in eastern regions and living on several species of *Ficus.* It was introduced into Italy in 2004 and seems to be widespread in Southern Europe (Italy, Spain and Malta) (Barbagallo et al. 2005a, Mifsud 1998). *Paoliella eastopi*, a species belonging to the Lizerinae described from Kenya, has only been found in one European country, England. All *Paoliella* species are of African origin. *Neophyllaphis podocarpi*, the only Neophyllaphidinae species known in Europe, originates from Asia and was recorded on *Podocarpus* in Italy in 1990 (Limonta 1990) but appears to have spread. Five subfamilies contribute more than five species to the alien fauna (Figure 9.2.1). The subfamily Aphidinae predominates, accounting for 59% of the alien Aphididae, followed by Calaphidinae (16%), Lachninae (5.8%), Eriosomatinae (4.8%) and Chaitophorinae (4.8%). These five subfamilies are also the most species-rich in native species. Each of the other seven subfamilies accounts for less than 1% of the alien Aphididae (Figure 9.2.1). The Hormaphidinae is the only subfamily represented by more alien than native species (4 species vs 1).

The taxonomic composition of the alien entomofauna is highly diverse at genus level. The 102 alien species belong to 58 different genera (Table 9.2.1). Thirty-two (55%) of these genera are represented in Europe by only non-native species and 40 (69%) contribute only one species to the alien fauna. The genus *Aphis* is the most represented, with eight species. This is not surprising, given that this genus contains more than 10% of the world's Aphididae and is abundant in all biogeographical regions of the world. This is not the case for another two species-rich genera, the North American *Illinoia* (seven alien species *in* Europe and 54 species worldwide) and the Asian *Tinocallis* (six alien species *in* Europe and 25 species worldwide). Although the genus *Cinara* is the second most species-rich genus in the world, with 222 species worldwide, three quarters of which being of non-European origin, surprisingly only three alien species from this genus are present in Europe

9.2.3. Temporal trends

The date of the first record in Europe is known, with various degrees of precision, for 94 of the 102 alien aphid species (Table 9.2.1). The precise date of arrival is unknown for most species because their introduction was unintentional (see below 9.2.5) and large delays may occur between the date of introduction and the date of reporting. However, in certain cases, introduction is relatively well documented, available data suggesting that the date of the first report was close to the date of introduction. This is the case for recent introductions, such as the species detected and monitored by the permanent aerial suction-trap network "Euraphid". This system of aphid flight surveys, based on a 12.2 m.-high suction trap, was developed by the Rothamsted Experimental Station in the 1960s (Taylor and Palmer 1972). This device is now used in several European countries, as part of integrated control networks, and has also proved useful for studies of the long-range dispersal of alates and for the regular detection of

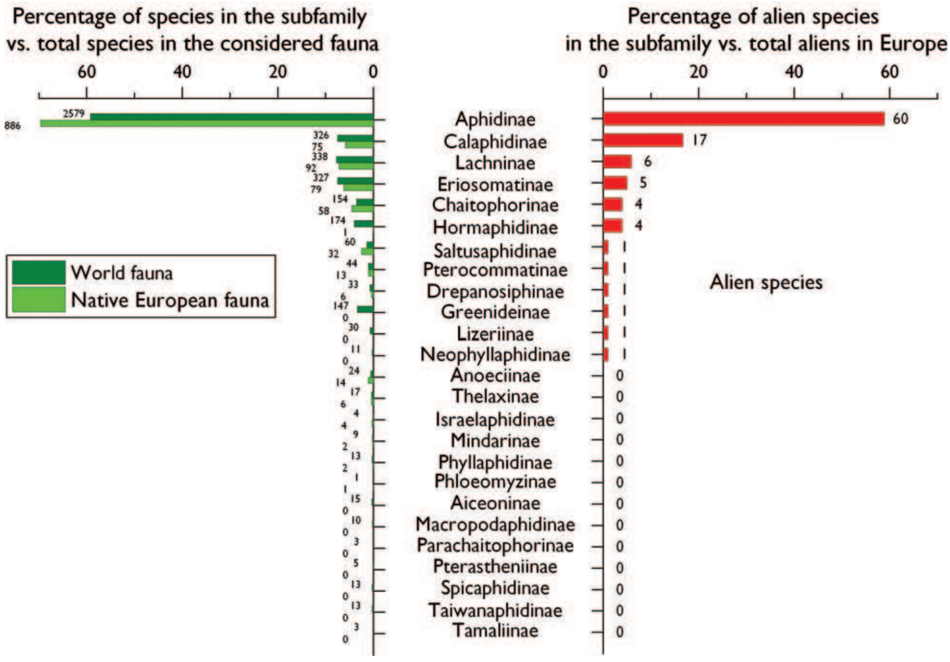

Figure 9.2.1. Taxonomic overview of the aphid species alien to Europe compared to the native European fauna and the world fauna. Subfamilies are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. Data about native European aphids from Fauna europaea (Nieto Nafria et al. 2007); world data from Remaudière and Remaudière (1997). The number over each bar indicates the number of species observed per subfamily.

aphid species new to the national or European fauna (Hullé et al. 1998). In France, a network of five such traps spread over the territory has been monitoring the aphid species trapped since 1978. This system detected four species new to Europe between 1984 and 1988 (Hullé et al. 1998): *Essigella californica* (Turpeau and Remaudière 1990), *Klimaszewskia salviae* (Leclant and Remaudière 1986), *Myzocallis walshii* (Remaudière 1989), and *Tinocallis takachihoensis* (Leclant and Remaudière 1986), and has monitored the extension of their geographical range in France. In a very small number of cases, more ancient introductions have also been documented, generally for important pest species. For example, the occurrence of *Eriosoma lanigerum*, a pest of apple trees originating from North America, was noted for the first time in a nursery in the outskirts of London in 1787 (Balachowsky and Mesnil 1935). The species was described by Hausmann in 1802, based on material from Germany, where aphids had been found in nurseries, causing extensive damage. In 1812, the species was found in France, by 1841, it was found in Italy and in 1870 it was reported in Switzerland. *E. lanigerum* has subsequently spread gradually to all temperate countries of the world (Balachowsky and Mesnil 1935, Marchal 1928).

For most alien species, the date of first report sighting may not correspond to the date of introduction and secondary expansion. For example, the pest species *Myzus persicae*, *Panaphis juglandis*, and *Chromaphis juglandicola* were all reported for the first time in Europe between 1800 and 1849, but they were probably introduced long before along with their host plants. The primary host of *Myzus persicae,* the peach tree, grown since classical times in the Mediterranean basin, was imported to Europe from Persia, but probably originated from western China, where it has been cultivated since 5,000 yr BP (Faust and Timon 1995). The host plant of *Chromaphis juglandidola* and *Panaphis juglandis,* the walnut, may have been introduced to Europe from Persia during the classical era, but this remains a matter of debate (Huntley and Birks 1983). Even for more recent introductions, the time lag between introduction and the first reported sighting may be considerable, particularly if the species concerned is not a pest. The date on which a taxonomic group was first recorded is therefore more likely to refer to the period during which it was studied for the first time. Börner between 1930 and 1952 made the largest single advance to studies of the aphid fauna of Europe, with the publication of "Europae Centralis Aphid" (Börner 1952). This catalysed intensive studies of the aphid fauna in various European countries over the following 20 years. The increase in the number of introduced species observed between 1950 and 1974 is partly attributable to this increase in taxonomic and faunistic activity.

Bearing these biases in mind, and taking the first recorded sighting as a proxy for the date of introduction, the mean rate of introduction since 1800 was 0.5 species per year. A similar rate has also been reported for a more recent period (0.42 between 2000 and 2007). The number of introductions increased in the second half of the 20th century (Figure 9.2.2). The mean number of new records increased from 0.3–0.4 per year before 1950 to more than 1.3 per year between 1950 and 1974. The mean number of introductions per year has decreased since 2000, but this pattern may change again in the future. The three most recent alien aphid species introduced to Europe are *Aphis illinoisensis*, a Nearctic species and a pest of vineyards introduced into Crete in 2005 (Tsitsipis et al. 2005), *Prociphilus fraxiniifolii*, also of Nearctic origin, introduced into Europe in 2003, (Remaudière and Ripka 2003), and *Greenidea ficicola*, a tropical species, probably originating from Asia, introduced into Sicily in 2004 (Barbagallo et al. 2005a).

9.2.4. Biogeographic patterns

9.2.4.1 Origin of alien species

A precise continent of origin was ascertained for 90.2% (92 species) of the alien Aphididae species, whereas 5.9% (six species) of the alien species were known only to be native to tropical or subtropical regions and 3.9% (four species) were of unknown origin (cryptogenic, Table 9.2.1, Figure 9.2.3).

The cryptogenic species include the polyphagous pest species *Myzus persicae* and *M. cymbalariae*, which have a cosmopolitan distribution. Data concerning their host plant relationships and the distribution of other species of the genus *Myzus*, strongly

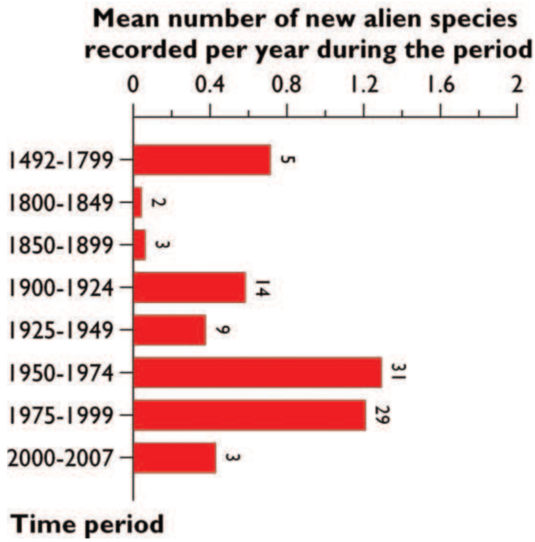

Figure 9.2.2. Changes over time in the mean number of first sightings per year of aphid species alien *to* Europe from 1492 to 2007. The number to the right of the bar indicates the absolute number of species reported for the first time during the corresponding time period.

suggest that these species originate from a continent other than Europe. Many other cosmopolitan species are not included in this list because they are thought to be of European origin, e.g. *Acyrthosiphon pisum*, *Brevicoryne brassicae*, although their origin is unclear and it remains possible that they were introduced into Europe by humans a long time ago.

Most of the alien aphid species in Europe originate from temperate regions of the world. Asia and North America have contributed the largest numbers (each 43.1%, Figure 9.2.3). Most of the Asian species originated from temperate zones (32 species), and only four species (*Cerataphis brasiliensis*, *Cerataphis orchidearum*, *Greenidea ficicola*, and *Stomaphis mordvilkoi*) are known to have originated from tropical Asia. Only four alien species in Europe are of African origin. Two of these species come from North Africa (*Cinara laportei* and *C. cedri*) and two from sub-Saharan regions (*Aloephagus myersi* and *Paoliella eastopi*). No alien aphid species has yet been introduced into Europe from Australasia or South America. The proportions of aphids of different geographical origins in the alien aphid fauna of Europe have remained fairly constant over time (Figure 9.2.4) and seem to reflect the species diversity of the donor continents. Most of the described aphid species are of temperate origin, with Aleyrodidae and Coccoidea appearing to replace aphids in the tropics and subtropics (Dixon 1998). With only 219 (Remaudière et al. 1985) and 180 (Hales 2005) species, respectively, sub-Saharan Africa and Australia have a very poor aphid fauna. By contrast, 1,416 species are found in North America (Foottit et al. 2006) and 1,007 species are found in China (Qiao and Zhang 2004). Thus, the origins of the alien species in Europe might reflect regional species di-

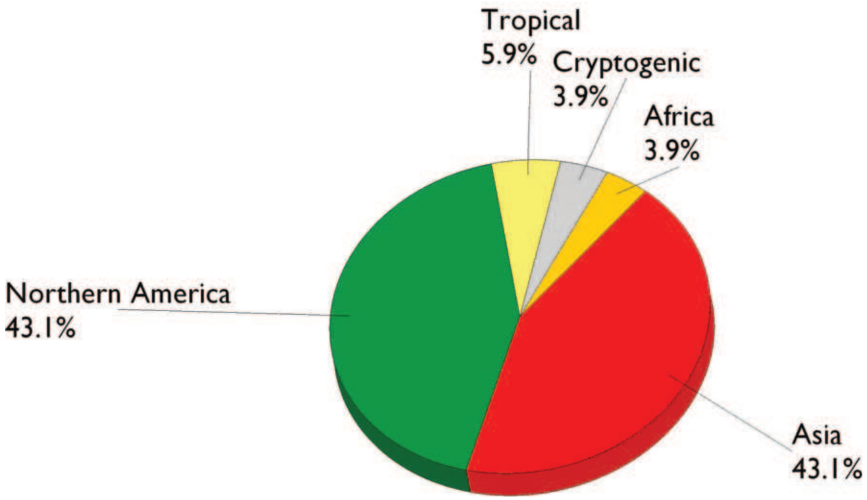

Figure 9.2.3. Geographic origin of the alien species of Aphididae established in Europe.

versity rather than preferential routes of introduction from North America and temperate Asia.

9.2.4.2. Distribution of alien species in Europe

Alien Aphididae species are not evenly distributed within Europe (Figure 9.2.5). The number of alien species present in a country is significantly and positively correlated with the number of native species recorded in that country ($r=0.6226$, $p<0.001$). This may reflect differences in sampling intensity and in the number of local taxonomists. The number of alien species also seems to be weakly positively correlated with the total area covered by each country ($r=0.3361$, $p=0.0182$). Similarly, the number of native species is strongly correlated with the area of the country ($r=0.6803$, $p<0.001$).

The top ten countries/regions within Europe with the largest numbers of recorded alien aphid species are: Great Britain (64), mainland France (63), mainland Italy (58), mainland Spain (56), Sicily (Italy) (45), Germany (44), Switzerland (37), Madeira (Portugal) (36), mainland Portugal (31), Czech Republic (29).

Alien aphid species are well distributed across Europe, with 58% present in at least five European countries and 38% occurring in more than 10 countries or regions. The polyphagous pest species, *Myzus persicae*, *Macrosiphum euphorbiae* and *Aphis gossypii* are the most widely distributed alien species: they have been recorded in 43, 41 and 40 countries or regions, respectively. Only one of the 15 species occurring in more than half of the countries of Europe, *Acyrthosiphon caraganae*, is not considered to be a pest of crop plants. This species, probably originating from the Altai region, is now found in temperate regions throughout the Northern hemisphere, where it lives on woody Leguminosae, particularly *Caragana* and *Colutea* species. In

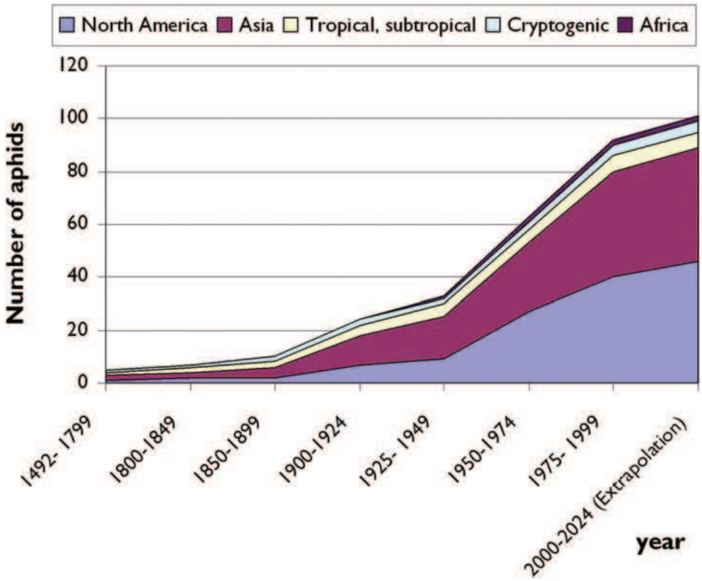

Figure 9.2.4. Cumulative numbers of alien aphid species established in Europe, by year and by geographic origin

most cases, it is not known whether the species expanded naturally after its establishment in a country, or whether the extension of its distribution was driven by repeated introductions from abroad.

Thirteen of the 19 species present in only two European countries have discontinuous distributions, probably resulting from independent introductions. Thus, for example *Ericaphis wakibae* has been found in Great Britain and the Czech Republic, *Chaitophotus populifolii* in Germany and Serbia and *Macrosiphum ptericolens* in Poland and Great Britain. A continuous but restricted area may be accounted for by recent introductions, as for *Aphis illinoisensis* Shimer, 1866, a pest of grapevines introduced into Greece in 2005 (Tsitsipis et al. 2005). This species has extended its range from Crete to continental Greece and recently (2007) to the Mediterranean part of Montenegro (Petrovic, personal communication).

Eight alien aphid species have each been found in only one European country. Four of these species are confined to England, two to Italy, one to Swirtzerland and one to the Ukraine. These species were all introduced before 2000 and have not spread elsewhere since. They may be unable to colonise a wider geographical area in Europe, they may have disappeared or they may simply have been overlooked.

9.2.5. Main routes and vectors for introduction into Europe

No cases of intentional introduction of aphids into Europe are known. All alien species were therefore introduced accidentally. In a very small number of cases, the pathway

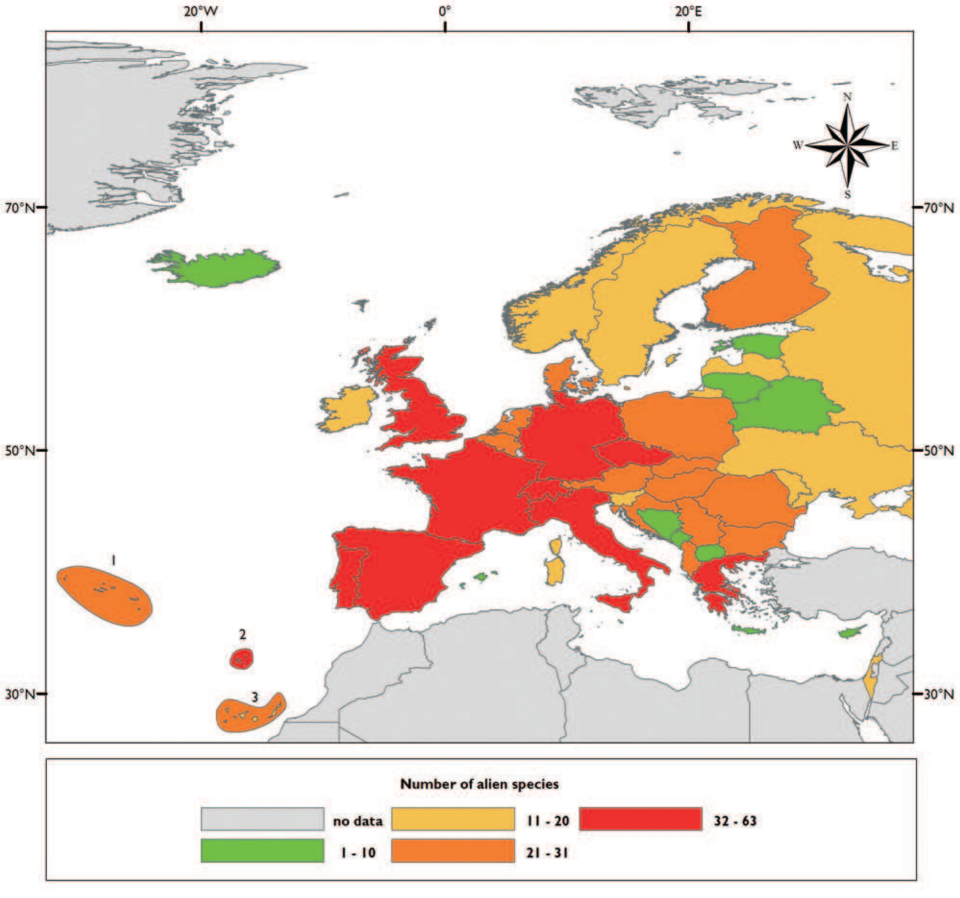

Figure 9.2.5. Comparative colonization of continental European countries and islands by Aphididae species alien to Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

and vector are precisely known. For example, two Japanese aphids, *Tinocallis ulmiparvifoliae* and *T. zelkovae* were introduced into Europe in 1973 with their hosts, bonsai trees that were imported into Great Britain directly from Japan. The infested bonsai trees had been in Great Britain for about six months before the aphids were detected, and were growing in slatted wood buildings providing no effective physical barrier to insect dispersal (Prior 1971).

In most cases, it is difficult to identify the vector of accidental introductions; most have been inferred from the known biological requirements of the aphid species. Most Aphididae have a high level of host-plant specificity and most alien species are therefore thought to have been introduced into Europe with their host plants. For example, the *Takecallis* species included in our list feed on bamboos of Asian origin. The Ne-

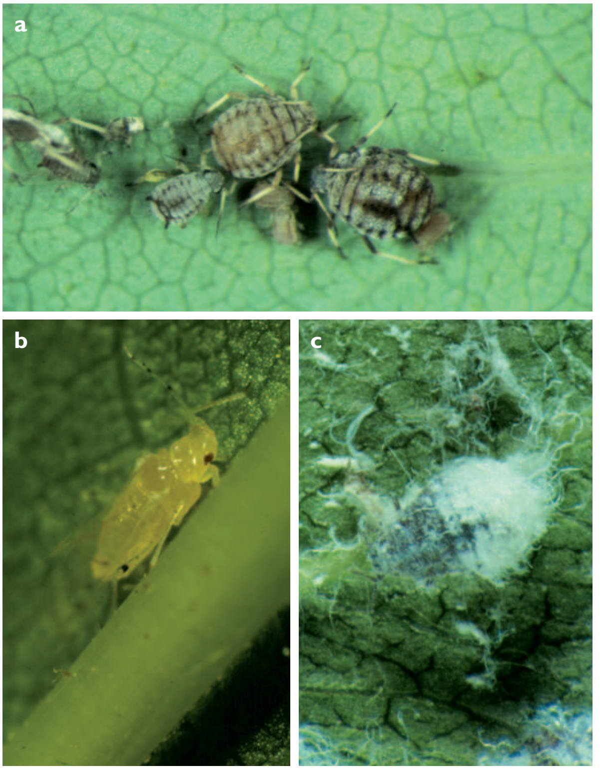

Figure 9.2.6. Some alien aphids. **a** Spiraea aphid, *Aphis spiraephaga*. (Credit: Olivera Petrović-Obradović) **b** Walnut aphid, *Chromaphis juglandicola*. (Credit: Olivera Petrović-Obradović) **c** Woolly apple aphid, *Eriosoma lanigerum*. (Credit: Olivera Petrović-Obradović).

arctic aphid *Prociphilus fraxinifolii* has recently been detected in Budapest (Hungary) (Remaudière and Ripka 2003), but only on the North American red ash tree, *Fraxinus pennsylvanica* Marsh. This aphid has not been found on European ash planted in the same area. Two oriental species, *Reticulaphis distylii* and *Greenidea ficicola,* live on several species of *Ficus,* all originating from tropical regions. These *Ficus* species have been planted as ornamental trees in the warmest areas of the Mediterranean basin (Barbagallo et al. 2005a). These two species of aphids are found on tropical fig trees, but never on *Ficus carica,* the only European species of this genus. All these alien species are thought to have been introduced into Europe through trade, but the aphid species may have been introduced several years after their hosts. *Impatientinum asiaticum* is a species originating from Central Asia. It was introduced into Europe in 1967, whereas its host, *Impatiens parviflora* DC. was introduced into Europe much earlier, in the 19th Century, subsequently escaping from botanic gardens to establish itself as a common weed. The aphid was not introduced at the same time as its host plant in this case because the host plant is an annual, which was imported in the form of seeds. The aphid arrived more than 100 years later, probably on an aeroplane (Holman 1971, Tambs-Lyche and Heie 1973). Another example is provided by *Rhopalosiphoninus latysiphon*, a pest species particularly damaging to potato. This species was not introduced into Europe until the end of the 1st World War, long after the introduction of its host plant, and was transported with potatoes from the USA. It was subsequently found in Italy (1921), the Netherlands (1930), Germany (1943), England (1945), Switzerland and Austria (1949) (Remaudière 1952).

Finally, we cannot exclude the possibility that some species originating in areas close to Europe may have been transferred into Europe by wind, air streams or windstorms. For example, it is difficult to determine whether *Cinara laportei* and *C. cedri* were transferred with their host, the Atlas cedar, which was planted in Europe, or whether these species colonised Europe following their introduction via wind or air streams.

9.2.6. The ecosystems and habitats most frequently invaded

All aphids are phytophagous and their distribution is limited by the presence of their host plants. Aphid species with a limited spectrum of host plants of exotic origin, not present at natural sites, are restricted to artificial habitats, such as agricultural land, greenhouses and parks and gardens. For example, *Illinoia liriodendri* and *Neophyllaphis podocarpi* feed on exotic trees (*Liriodendron tulipifera* L. and *Podocarpus* spp., respectively). As a result, these aphids are restricted to parks, gardens and city areas in which these trees have been planted in Europe. Similarly, *Cinara cedri* and *C. laportei* which feed specifically on *Cedrus* are restricted to forest areas in which their hosts have been planted. Other species restricted to artificial habitats include tropical and subtropical aphids present only in indoor conditions in Europe. These species were included in the list because it is clear that they have become established in Europe. For example, *Cerataphis* spp., particularly *C. lataniae* and *C. orchidearum* have repeatedly been found in European greenhouses (Chapin and Germain 2005). Similarly, *Sitobion luteum* and *Pentalonia nigronervosa* are considered to have been introduced into hothouses in Europe (Blackman and Eastop 2000). Another subtropical *Cerataphis*, *C. brasiliensis*, has recently been found established outdoors in the south of the France (Chapin and Germain 2005, 2004). Some aphid species have a less limited host range spectrum. They can adapt to new hosts when introduced and may disperse in natural habitats. *Cinara curvipes*, a species recently introduced into Europe, is known to feed on various species of *Abies* in its native area (North America). In Europe, it is found on North American *Abies* species, but also on native *Abies* species and has recently been reported on many other conifers, including *Picea*, *Tsuga*, and *Pinus* (Scheurer and Binazzi 2004). *C. curvipes* is found in parks, gardens and forests. It could potentially colonise all European coniferous forests. Finally, polyphagous aphids, notably *Myzus persicae*, *M. ascalonicus*, *M. ornatus*, *Macrosiphum euphorbiae* and *Aphis gossypi,* have established themselves on many native plants in natural habitats.

Most of the alien aphids seem to have become established in the European environment and habitats. However, some species, such as *Paoliella eastopi* and *Macrosi-*

phum ptericolens have been recorded only once or twice, and it remains unclear whether these species are truly established. Other species, such as *Rhopalosiphum parvae* Hottes & Frison (1931), a North American aphid found in Sicily in 1982 (Barbagallo and Stroyan 1982), or *Tuberocephalus higansakurae hainnevilleae* Remaudière & Sorin, 1993, detected in France in 1990 on trees of *Prunus subhirtella* Miq. var. *pendula* Y.Tanaka imported from Japan (Remaudière and Sorin 1993), have been observed in Europe but have since been eradicated. Such species are not included in our list.

9.2.7. Ecological and economic impact

Most of the alien Aphididae are recognised pests, feeding on crops, ornamental plants and forest trees in Europe. Other alien Aphididae species may have remained undetected because they feed on plants that are not commercially exploited. As for most insects, much more is known about the economic impact of aphids than about their ecological impact. Aphids cause direct (sap-feeding, deformation of their hosts) and indirect (transmission of plant diseases, deposition of honeydew on the leaves) damage.

The economic impact of each species depends on (i) the type and extent of the damage caused and (ii) the economic importance of the host. Of the 102 alien aphid species in Europe, 52 are recognised pests of agricultural and horticultural crops (Blackman and Eastop 2000). The polyphagous species *Myzus persicae*, *Macrosiphum euphorbiae* and *Aphis gossypii* attack a wide range of vegetable crops, both indoors and outdoors. They are vectors of many viral diseases and are probably the aphids with the greatest economic impact in vegetable crops (Lampel and Gonseth 2005).

European orchards are attacked by several alien aphid species. Apple trees can be severely damaged by the North American wolly aphid *Eriosoma lanigerum* and the Asian species *Aphis spiraecola.* The recent introduction of *Toxoptera citricidus* into the Iberian Peninsula (Portugal and Spain) (Ilharco et al. 2005) poses a serious threat to Mediterranean citrus fruit production because this aphid is the principal vector of the *Triteza* closterovirus of *Citrus*. *Citrus* trees in Europe are also the hosts of *Aphis spiraecola* and *Toxoptera aurantii,* two polyphagous species also capable of transmitting this closterovirus, albeit with a lower efficiency.

The recent introduction and rapid dispersion of *Aphis illinoiensis,* a grapevine aphid, poses a particular threat to viticulture in the Mediterranean area (Remaudière et al. 2003, Tsitsipis et al. 2005). Some alien aphids attack agricultural crops, often as potential virus vectors. *Rhopalosiphum maidis* is known as a pest of maize and other grain crops in Europe and transmits the persistent luteovirus "yellow dwarf" virus of barley. The grass aphid, *Hysteroneura setariae* Thomas, 1878, has recently been recorded in Spain (Meliá Masiá 1995). Its impact it difficult to predict because it usually lives on wild grass species, but it may occasionally infect cereals and can transmit several viral diseases to these crops. *Macrosiphum albifrons* is a widespread species in North America that has been introduced into Europe (Stroyan 1981) where the damage it causes to lupins (Ferguson 1994) has stimulated recent research (Blackman and Eastop 2000). Finally, *Acyrthosiphon kondoi*, which currently has a restricted distribution in Europe, is known to be a serious pest of lucerne (Blackman and Eastop 2000).

Exotic Aphididae are not considered to be serious pests of forest species in Europe (EUROFOR 1994) by contrast to the major damage caused to agricultural and horticultural crops. However, some species may cause economic losses. For example, the North African species *Cinara cedri* and *C. laportei* have been reported to damage plantations of *Cedrus* in southern France (Emonnot et al. 1967, Fabre 1976).

Finally, in addition to their measurable economic impact, some alien aphids may have an aesthetic impact. The production of abundant honeydew and the distortions induced by feeding may significantly modify the appearance of the foliage of ornamental plants in parks and private gardens. *Appendiseta robiniae* has such an aesthetic impact on *Robinia pseudacacia* L., as does *Prociphilus fraxinifolii* on the red ash tree *Fraxinus pennsylvanica* and *Illinoia liriodendri* on *Liriodendron tulipifera*.

9.2.8. Conclusion

There are several possible reasons for the overrepresentation of Aphididae in the alien insect fauna of Europe. First, aphids are phytophagous insects and many are pests of economically important host plants (Blackman and Eastop 2000). For this reason, many studies are carried out on the distribution, taxonomy and biology of this family. New alien species of Aphididae are therefore more likely to be detected than new members of other taxonomic groups, and this effect is enhanced by standard phytosanitary procedures. Second, aphids have the ability to reproduce both parthenogenetically and sexually. Several species can reproduce exclusively by parthenogenesis, and all species can potentially maintain parthenogenetic populations throughout the year in areas of mild climate. Consequently, very few introduction events, and theoretically even the introduction of a single parthenogenetic female, may lead to the development of a population and the establishment of an alien species. Third, although aphids, as a group, are cosmopolitan, they are most strongly represented in temperate regions. Consequently, most of the World's aphids live in climatic conditions similar to those of Europe and are therefore preadapted to establishment where suitable hostplants are present. Moreover, global warming is also likely to promote the survival of alien tropical and subtropical species, at least locally (e.g. along the Mediterranean coast). Finally, aphids are small insects easily transported around the globe with plant materials.

These factors and trends are unlikely to change and the number of introductions of alien Aphididae observed in Europe will probably continue to increase, due to both environmental (climate change) and economic factors (expanding markets and globalisation, and the ever increasing numbers of goods transported and agents of transport).

References

Aguiar AMF, Fernandez A, Ilharco FA (1994) On the sudden appearance and spread of the black citrus aphid *Toxoptera citricidus* (Kirkaldy) (Homoptera Aphidoidea) on the island of Madeira. *Bocagiana* 168: 1–7.

Aguiar AMF, Ilharco FA (1997) New records for aphids (Homoptera: Aphidoidea) from Madeira Island. *Boletín de Sanidad Vegetal* – 23: 565–570.

Aguiar AMF, Ilharco FA (2001) Aphids (Homoptera : Aphidoidea) from Madeira Island – New records and Corrections. *Boletín de Sanidad Vegetal - Plagas* 27: 323–336.

Angst A, Scheurer S, Forster B (2007) First record of Cinara curvipes (Patch) (Homoptera, Aphididae, Lachnidae) on Abies concolor in Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 80: 247–252.

Arzone A, Vidano C (1990) Exotic insects newly introduced in Italy and Piedmont. *Informatore Fitopatologico* 40: 47–54.

Balachowsky A (1933) I. Sur la présence en France de *Capitophorus fragaefolii* Ckll., Aphide nouvellement introduit et nuisible au frasier. II. Sur l'existence de nouveaux foyers d'*Aphis forbesi* Weed. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 20: 256–267.

Balachowsky A, Mesnil L (1935) Les insectes nuisibles aux plantes cultivées. Paris, France: Mery L. 1921 pp.

Barbagallo S (1994) Considerazioni faunistiche e biogeografiche sugli afidi italiani. *Atti Accademia Nazionale italiana di entomologia* XLII: 141–178.

Barbagallo S, Stroyan HLG (1982) Osservazioni biologiche, ecologiche e tassinomiche sull'afidofauna delle Sicilia - Biological, ecological and taxonomic notes on the aphid fauna of Sicily. *Frustula Entomologica (N.S.)* 3: 1–182.

Barbagallo S, Coccuzza GE (1998) Sulla presenza in Sicilia dell'afide *Neotoxoptera violae* (Pergande). *Bolletino di Zoologia Agraria e di Bachicoltura* 30 (2): 321–326.

Barbagallo S, Bosio G, Brussino G, Scarpelli F (1998) Aphids infesting cultivated blueberries and cranberries in Italy. *Informatore Fitopatologico* 10: 65–71.

Barbagallo S, Bosio G, Brussino G, Patti I, Scarpelli F (1999) Annotazioni morfo-biologiche sull'afide dei Mirtilli americani, Ericaphis scammeli (Mason) (Rhynchota Aphidoidea). *Bollettino di Zoologia Agraria e di Bachicoltura* 31: 207–227.

Barbagallo S, Suma P (1999) Recenti infestacioni in Sicilia dell'afide giallo del Pecan, *Monelliopsis pecanis* Bissell. *Bollettino di Zoologia Agraria e di Bachicoltura* 31: 241–249.

Barbagallo S, Ciampolini M (2000) Rinvenimento in italia dell' afide della cipolla *Neotoxoptera formosana* (Takahashi). *Bollettino di Zoologia Agraria e di Bachicoltura* 32: 245–258.

Barbagallo S, Bella S, Cocuzza G (2005) Rinvenimento dell'afide orientale *Greenidea ficicola* su Ficus ornamentali in Italia meridionale. *Informatore Fitopatologico* 55: 25–29.

Barbagallo S, Ilharco FA, Nieto Nafria JM, Sousa-Silva RC (2005) D Recent aphid records in Southern Europe: Towards the tropicalization of the Mediterranean ?. 7 th International Symposium on Aphids, Freemantle, WA Australia. 2–7. October 2005.

Binazzi A, Barbagallo S (1991) Annotazioni faunistico-ecologiche sugli afidi del genere *Chaitophorus* Koch in Italia. XVI. Congr. Naz. Ital. Entomol., Settembre 1991, pp. 59–63.

Biurrun R, Nieto Nafría JM (1987) Sobre la presencia en España de *Illinoia azaleae* (Mason, 1925) (Hom., Aphididae). *Boletín de la Asociación Española de Entomologí.* 11:418.

Blackman RL, Eastop VF (1994) *Aphids on the World's Trees: an Identification and Information Guide*. Wallingford, UK: CAB International. 1024 pp.

Blackman RL, Eastop VF (2000) *Aphids on the World's Crops - an Identification and Information Guide.* 2nd edn. Chichester UK: John Wiley & Sons. 476 pp.

Blackman RL, Eastop VF (2006) *Aphids on the world's herbaceous plants and shrubs*. Chichester, UK: John Wiley & Sons. 1460 pp.

Blackman RL, Eastop VF (2007) Taxonomic Issues. In Van Emden H, Harrington R., *Aphids as Crop Pests*. CAB International, 1–29.

Blanchard E (1840) *Aphidiens. Histoire Naturelle des insectes. Orthoptères, Hémiptères, Hyménoptères, Lépidoptères et Diptères.* Paris, France: Duménil. 672 pp.

Boisduval JA (1867) Essai sur l'entomologie horticole comprenant l'histoire des insects nuisibles à l'horticulture avec l'indication des moyens propres à les éloigner ou à les détruire, et l'histoire des insectes et autres animaux utiles aux cultures. Paris, France: Librairie Centrale d'Agriculture et de Jardinage. 664pp.

Börner C (1952) Europae centralis Aphides. Die Blattläusse Mitteleuropas. Namen, Synonyme, Wirtspflanzen, Generationszyklen. *Mitteilungen der Thüringischen Botanischen Gesellschaft* 3:1–488.

Bozhko MP (1976) New and little known aphids (Homoptera, Aphidoidea) in the south of the European part of the USSR (in Russian). *Entomologicheskoe Obozrenie* 55: 863–874.

Boyer de Foscolombe M (1841) Description des pucerons qui se trouvent aux environs d'Aix. *Annales de la Société Entomologique de France* 10:157–198.

Buckton GB (1876) *Monograph of the British aphides Vol.I.* London, UK: The Ray Society. 190pp. + 38 plates.

Buckton GB (1879) *Monograph of the British aphides Vol.2.* London, UK; The Ray Society. 176pp.

Cairaschi EA (1942) *Pentalonia nigronervosa* Coquerel (Hem. Aphididae) espèce nuisible nouvellement introduite en France. *Bulletin de la Société entomologique de France* 46: 138–140.

Carter CI, Four DF, Bartlett PW (1984) The lupin aphid's arrival land consequences. *Antennata* 8: 129–182.

Chapin E, Germain JF (2005) Un nouveau puceron des palmiers pour la côte varoise. *PHM Revue Horticole* 466: 41–45.

Cholodkovsky N (1907) On the biology of aphids on papilionaceous plants. *Russkoe ėntomologicheskoe obozrienie* 2–3: 87–95.

Ciampolini M, Martelli M (1977) Appearance in Italy of the peach trunk aphid *Pterochloroides persicae* (Cholodk.). *Bolletino di Zoologia Agraria e di Bachicoltura* 14: 189–196.

Coceano PG, Petrovic-Obradovic O (2006) New Aphid species for Italy caught by suction trap. *Phytoparasitica* 34: 63–67.

Colombo M (1981) *Stomaphis mordvilkoi* Hille Ris Lambers (Aphidoidea Lachnidae) afide orientale riscontrato su noce nell'Italia del Nord. *Bollettino di Zoologia Agraria e di Bachicoltura ser. II* 16: 199–206.

Covassi M (1971) Osservazioni preliminari sulla presenza in italia di un afide nocivo ai cedri: *Cedrobium laportei* Remaud. (Homoptera, Aphidoidea, Lachnidae). *Redia* 52: 641–652

Covassi M, Binazzi A (1974) Note corologiche e morfologiche sulla *Cinara cedri* Mim. In Italia (Homoptera Aphidoidea, Lachnidae). *Redia* 55: 331–341.

Del Guercio G (1911) Intorno ad alcuni Afididi della Penisola Iberica e di altre localita, raccolti dal prof. I.S. Tavares. *Redia* 11: 296–333.

Del Guercio G (1913) Generi e specie nuove di afidi o nuovi per la fauna italiana. *Redia* 9: 169–196.

Del Guercio G (1917) Contribuzione alla conoscenza degli afidi. *Redia* 12: 197–277.

Dixon AFG (1998) *Aphid Ecology* 2nd edn. London, UK: Chapman & Hall. 300 pp.

Doncaster JP (1946) The shallot Aphis, *Myzus ascalonicus* sp. n. (Hemiptera, Aphididae). Proceeding *of the Royal Entomological Society (Lond.)* 15: 17–48.

Doncaster JP (1954) Two aphids new to Britain. *Entomologist* 87: 127–128.

Doncaster JP (1961) *Francis Walker's aphids.* London, UK: Britsih Museum (natural History). 165pp.

Dospevski S (1910) Bolesti i nepriyateli na kulturnite rasteniya za unischtozenietona koito sa iskani nastavleniya ot stantziyavata i takiva, nabyudavani v Sadovo prez 1908 godina, Godischen otchet na Durzavnata opitna zemedelska stanciya v Sadovo.

Eastop VF (1956) Thirteen aphids new to Britain and records of some other rare species. *Entomologist's Monthly Magazine* 92: 271–275.

Eastop VF (1958) The history of *Macrosiphum euphorbiae* (Thomas) in Europe; The Entomologist 91: 198–201.

Eastop VF (1962) Additions to the wild fauna and flora of the Royal Botanic Gardens, Kew. 25. A contribution to the aphid fauna. *Kew Bulletin* 16: 139–146.

Eastop VF (1971) Keys for the identification of *Acyrthosiphon* (Hemiptera: Aphididae). *Bulletin of the British Museum (Natural History) Entomology* 26: 1–115.

Eastop VF, Hille Ris Lambers D (1976) *Survey of the World's Aphids*. The Hague, Netherlands: Dr Junk W. b.v. 573 pp.

Eastop VF, Blackman RL (2005) Some new synonyms in Aphididae [Homoptera: Sternorrhyncha]. *Zootaxa* 1089: 1–36.

Emonnot P, Gayraud Y, Leclant F, Remaudière G (1967) Sur la présence en France de *Cedrobium laportei* Remaudière puceron nuisible au cèdre. *Comptes-Rendus de l'Académie d'Agriculture de France* Juin 1967: 966–972.

EUROFOR (1994) L'europe et la forêt: Les grands problèmes des forêts de l'union européenne - Dégâts occasionnés aux forêts et conséquences pour l'environnement. http://www.europarl.europa.eu/ workingpapers/agri/ch4–3_fr.htm.

Fabre JP (1976) Sur la présence en France de *Cinara cedri* (Mimeur) puceron nuisible au cédre. *Comptes-Rendus de l' Académie d'Agriculture de France* Juin 1976: 771–775.

Faust M, Timon B (1995) Origin and dissemination of peach. *Horticultural Review* 17: 331–379.

Ferguson AW (1994) Pests and plant injury on lupins in the south of England. *Crop Protection* 13: 201–210.

Foottit RG, Halbert SE, Miller GL, Maw E, Russell LM (2006) Adventive aphids (Hemiptera: Aphididae) of America north to Mexico. *Proceedings of the Entomological Society of Washington*. 108: 583–610.

Geiter O, Homma S, Kinzelbach R (2002). *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Forschungsbericht 296. Berlin: Umweltbundesamt. Texte. 25/2002

Germain JF, Chapin E (2004) Discovery in France of the palm aphid *Cerataphis brasiliensis* (Hempel) (Hemiptera, Aphididae, Hormaphidinae). *Revue Francaise d'Entomologie (N.S.)* 26: 174.

Germain JF, Deogratias JM (2008) Confirmation de la presence en France du puceron de la violette. *PHM-revue Horticole*, 507: 42–44.

Giacalone I, Lampel G (1996) Pucerons (Homoptera, Aphidina) de la région insubrique tessinoise d'origine subméditerranéenne, méditerranéenne, esteuropéenne, asiatique et américaine. *Mittelungen der schweizeischen entomologschen Gesellschaft* 69: 229–260.

Goeze JA (1778) *Hemiptera. Entomologische Beyträge zu des ritter Linné Zwölften ausgabe des Natursystems*. Leipzig, Germany: Weidmann. 352pp.

Hales D (2005) *Aphidoidea in Australia*. 7 th International Symposium on Aphids, Freemantle, WA Australia: 2–7 October 2005.

Heie OE (1973) Tilfojelser til listen over danske bladlus (Homoptera, Aphidoidea). *Entomologiske Meddelelser* 41: 177–187.

Heie OE (1980) The Aphidoidea of Fennoscandia and Denmark. I General Part. The families Mindaridae, Hormaphididae, Thelaxidae, Anoeciidae and Pemphigidae. *Fauna Entomologica Scandinavica* 9: 1–236.

Heie OE (1982) The Aphidoidea of Fennoscandia and Denmark. II The family Drepanosiphidae. *Fauna Entomologica Scandinavica* 1I: 1–176.

Heie OE (1986) The Aphidoidea of Fennoscandia and Denmark. III The family Aphididae: subfamily Pterocommatinae, tribe Aphidini of subfamily Aphididae. *Fauna Entomologica Scandinavica* 17: 1–314.

Heie OE (1992) The Aphidoidea of Fennoscandia and Denmark. IV Family Aphididae: Part 1 of the tribe Macrosiphini of subfamily Aphidinae. *Fauna Entomologica Scandinavica* 25: 1–188.

Heie OE (1994) The Aphidoidea of Fennoscandia and Denmark. V Family Aphididae: Part 2 of the tribe Macrosiphini of subfamily Aphidinae. *Fauna Entomologica Scandinavica* 28: 1–239.

Heie OE (1995) The Aphidoidea of Fennoscandia and Denmark. VI Family Aphididae: Part 3 of tribe Macrosiphini of subfamily Aphidinae, and family Lachninae. *Fauna Entomologica Scandinavica* 31: 1–217.

Hermoso de Mendoza (1988) Primera cita en Espana de *Monellia caryella* (Fitch, 1855) (Hom., Aphidinea, callaphididae). *Boletín de la Asociación Española de Entomología* 12: 359.

Hille Ris Lambers D (1947) Neue Blattläuse aus des Schweiz II. Mitteilungen der Schweizerischen *Entomologischen Gesellschaft* 20: 649–660

Hille Ris Lambers D (1966) New and little known members of the aphid fauna of Italy (Homoptera, Aphididae). *Bolletino di Zoologia agraria e di bachicoltura, serie II* 8: 1–32.

Hille Ris Lambers D (1973) *Masonaphis lambersi* MacGillivray, 1960 (Homoptera, Aphididae), a new pest of Rhododendron in Europe. *Netherlands Journal of Plant Pathology* 79: 159–161.

Holman J (1965) Some unrecorded Middle European aphids. *Acta Faunistica Entomologica Musei Nationalis Pragae* 11: 277–283.

Holman J (1971) Taxonomy and Ecology of *Impatientinum asiaticum* Nevsky an aphid species recently introduced to Europe (Homoptera, Aphididae). *Acta Entomologica Bohemoslovaca* 68: 153–166.

Holman J (2009) Host Plant Catalog of Aphids-Palaearctic Region. New York, USA: Springer Verlag. 1216pp.

Holman J, Pintera A (1981) Übersicht der Blattläuse (Homoptera, Aphididoidea) der Rumänischen Sozialistischen Republik. Praha, Ceskoslovenska: Akademie Ved. 125 pp.

Hržič A (1996) Opazovanje naleta listnih uši (Aphididae) v letu 1994 (in Slovenian) [Observation of aphid flight in the year 1994]. *Slobodno kmetijstvo* 29: 54–56.

Hullé M, Renoust M, Turpeau E (1998) New aphid species detected by permanent aerial sampling programmes in France. In: Nieto Nafria JM, Dixon AFG (Eds) *Aphids in Natural and Managed Ecosystems*. León, Spain: Universidad de León, Secretariado de Publicaciones. 365–369.

Huntley B, Birks HJB (1983) *An Atlas of Past and Present Pollen Maps for Europe: 0–13,000 BP Years Ago*. Cambridge-London-New York-New Rochelle-Melbourne-Sydney: Cambridge University Press. 667 pp.

Ilharco FA (1960) The knowledge of aphids in Portugal. *Broteria* 29: 150–174.

Ilharco FA (1961) On an aphid collection found in the Estçap Agronomica Nacional, including a new species, *Paraschizaphis rosazevedoi*. *Agros* 44: 71–77.

Ilharco FA (1968) Algumas correcçoes e adiçoes a lista de afidios de Portugal Continental. I Parte. *Agronomia Lusitana* 29: 117–139.

Ilharco FA (1968) Algumas correcçoes e adiçoes a lista de afidios de Portugal Continental. II Parte. *Agronomia Lusitana* 29: 221–245.

Ilharco FA (1969) Algumas Correcçoes e adiçoes a lista de afidios de Portugal Continental. III Parte. *Agronomia Lusitana* 41: 313- 321.

lharco FA (1973) *Catálogo dos Afidos de Portugal Continental*. Oeiras, Portugal: Estação Agronómica National. 134 pp.

Ilharco FA (1974) List of the aphids of Madeira Island (Homoptera, Aphidoidea). *Bocagiana (Museu Municipal de Funchal- História Natural)* 35: 1–44.

Ilharco FA (1984) New records to the aphid fauna of the archpelago of madeira [Homoptera, Aphidoidea]. *Boletim do musu Municipal do Funchal* 36: 177–206.

Ilharco FA, Sousa-Silva CR, Alvarez Alvarez A (2005) First report on *Toxoptera citricidus* (Kirkaldy) in Spain and continental Portugal (Homoptera, Aphidoidea). *Agronomia Lusitana* 51: 19–21.

Jurc M, Poljakovic-pajnik L, Jurc D (2009) The first recor of Cinara curvipes (Patch, 1912) (Homoptera, Aphididae) in Slovenia and its possible economic impact. *Zbornik Gozdarstva in Leasarstva* 88: 21–29.

Kaltenbach JH (1843) Monographie der familien der Pflanzenläuse (Phytophtires) - I. Theil Die Blatt- und Erdläuse (Aphidina et Hyponomeutes). *Aachen*: 223pp.

Koch CL (1855) Die Pflanzenläuse Aphiden, getreu nach dem liben abgebildet und beschrieben Heft IX. Nüremberg, Germany. 135–236.

Laing F (1923) Aphidological Notes (Hemiptera-Homoptera). *The Entomologist's Monthly Magazine* 59: 238–247.

Laing F (1932) A new aphid pest on violets. *The Entomologist's Monthly Magazine* 68: 52–53.

Lampel G (1983) Für die neue Blattlaus-Arten (Homoptera, Aphididna). *Mitteilungen der Schweirerischen Entomologischen Gesellschaft* 56: 125–162.

Lampel G, Gonseth Y (2005) Hemiptera- Aphidina. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Bern, Switzerland: Federal Office for the Environment FOEN. 157 pp.

Lawton JH, Eastop VF (1975) A bracken feeding *Macrosiphum* (Hem., Aphididae) new to Britain. *Entomologist Gazette* 26: 135–138.

Leclant F (1967) Un Aphididae americain nouveau pour la faune europeenne: *Nearctaphis bakeri* Cowen (Hom.). *Bulletin de la Société Entomologique de France* 72: 25–26.

Leclant F (1978) *Étude bioécologique des Aphides de la région méditerranéenne. Implications Agronomiques*. Montpellier, France: Université des Sciences et Techniques du Languedoc 1–43. 318 pp.

Leclant F, Renoust M (1986) Le puceron du Lagerstroemia, nouveau ravageur pour notre flore. *Phytoma Défense des cultures* Février 1986: 49–50.

Leclant F, Remaudière G (1986) Aphids new to France and Europe. *Aphidologist's Newsletter* 21: 8.

Limonta L (1990) Callaphididae (Aphidoidea) new to Italy. *Bollettino di Zoologia Agraria e di Bachicoltura, SerII* 22: 93–99.

Limonta L (2001) Heavy infestation of *Illinoia liriodendri* (Monell) (Rhynchota Aphididae) in gardens in northern Italy. *Bollettino di Zoologia Agraria e di Bachicoltura, SerII* 33: 133–136.

Lozzia GC, Binaghi P (1992) Entomofauna delle alberate cittadine e studio di un metodo di protezione integrata. *Disinfestazione* 9: 35–41.

Lucchi A, Pollini A (1995) Un nuovo fitomizo per la fauna italiana : l'afide callafidino *Tinocallis ulmiparvifoliae* Matts. (Rhynchota Homoptera). *Informatore Fitopatologico* 6: 31–32.

Macchiati L (1883) Fauna e flora degli afidi di calabria. *Bolletino della Societa Entomologica Italiana* 15: 221–287.

Malkov K (1908) Bolesti i povredi po kulturnte rastenia izprateni za izslevane v sadovskata opitna stancia prez 1907. Godishen otchet na durjavna zemlena opitna stancia v Sadovo. *Plovdiv 5* (1907): 207–274.

Mamontova VA (1955) *Dendrophilous aphids of the Ukraine.* Kiev,Ukraine: Academy des Sciences, Ukrainian SSR. 91pp.

Marchal P (1928) Etude biologique et morphologique du puceron lanigère du pommier [*Eriosoma lanigerum* (Hausmann)]. *Annales des Epiphyties* 14: 1–106.

Martin JH (2000) Two new british aphid introdcutions since 1999, in the contexte of other additions over the preceding thirty years (Sternorrhyncha: Aphidoidea). *Entomologist's Gazette* 51: 97–105.

Meier W, Schweizer C (1987) Macrosiphum albifrons, eine für die Schweiz und für Mitteleuropa neue Blattlausart auf Lupine. *Mitteilungen für die Schweizerische landwirtschaft* 87: 41–42.

Melia Masia A (1995) Novedades de la tribu Rhopalosiphina (Homoptera: Aphididae) para Europa y el este Ibérico. *Boletín de la Asociación Española de Entomología* 19: 131–139.

Meliá Masiá A (1998) Contribution to knowledge of the Macrosiphini (Aphididae) of Castellón (Spain): new records for the Spanish fauna. In: Nieto Nafría JM, Dixon AFG (Eds) *Aphids in natural and managed ecosystems*. León, Spain: Universidad de León, 379–383.

Micieli De Biase L (1988) L'*Aloephagus myersi* Essig (Homoptera-Aphididae) nuova specie per l'Italia su piante dei generi Aloe e Gasteria. *Informatore Fitopatologico* 3: 76–77.

Micieli De Biase L, Calambuca E (1979) L'*Appendiseta robiniae* (Gillette), nuova specie per l'italia su *Robinia pseudoacacia* L. *Informatore Fitopatologico* 11–12: 31–33.

Mier Durante MP, Pérez Hidalgo N (2002) Dos especies de Panaphidini (Hemiptera, Aphididae: Calaphidinae), propias de árboles ornamentales, introducidas en la Península Ibérica. *Boletim da Sociedade Portuguesa de Entomologia* 157 (Suppl. 6): 213–217.

Mifsud A (1998) A new tree dwelling aphid *Greenidea ficicola* Takahashi. *Bulletin of the Entomological Society of Malta* 1: 39–41.

Mimeur JM (1936) Aphididae (Hem.) d'Esspagne. *Boletin de la Sociedad Entomologica de Espana* 1936: 33–40.

Mordvilko AK (1914) *Insectes Hémiptères (Insecta Hemiptera). Volume I. Aphidoidea. Faune de la Russie et des pays limitrophes.* Petrograd, Russia: Musée Zoologique de l'Académie Impériale des Sciences. 236pp.

Műller FP (1974) *Aphis oenotherae*, Erstfunde in Europa und als potentieller Zierpflanzenschädling. *Entomologische Nachrichten Dresden* 18: 129–133.

Nieto Nafria JM (2007) Fauna Europaea: Aphididae. Fauna Europaea version 13. http://www.faunaeuro.org.

Nieto Nafría JM, Mier Durante MP (1998) *Fauna Ibérica. Hemiptera, Aphididae I.* Madrid, Spain: Museo Nacional de Ciencias Naturales, CSIC. 425 pp.

Nieto Nafria JM, Mier Durante MP, Remandiere G (1998) Les noms des taxa du groupe famille chez les Aphididae (Hemiptera). *Revue Française d'Entomologie* 19: 77–92.

Nobanis (2005) *European Network on Alien Invasive Species*. www.nobanis.com.

Ossiannilsson F (1959) Contributions to the knowledge of Swedish aphids. II. List of species with find records and ecological notes. *Kungl. LantbrHögsk. Annlr. Uppsala* 25: 375–527.

Paillot A (1928) Rapport sur le fonctionnement de la station entomologique de Saint Genis en laval. *Annales des Epiphyties* 14: 448.

Passerini G (1861) Additamenta ad indicem Aphidanarum quas hucusque in Italia legit. *Atti della Societa Italiana de Scienze Naturali Milano* 3: 398–401.

Patti I (1983) Nuovi reperti sulla composizione dell'afidofauna Siciliana. *Bolletino del laboratorio di Entomologia Agraria "Filippo Silvesrtri" di portici* 40: 33–53.

Pati I (1984) Un afide nocivo alla *Lagerstroemia* in Italia. *Informatore Fitopatologico*: 12, 12–14.

Pati I, Tomatore MG (1988) Utilita delle trappole ad aspirazione di tipo Rothamstead nel censimento faunistico degli Afidi. Atti XV *Congresso Nazionale Italiano* di Entomologia, L'Aquila, 925–932.

Pedro Mansilla J, Pérez R, Pérez N, Seco V, del Estal P (2001) Presencia de Tuberculatus kuricola (Hemiptera: Aphididae) spbre catasnos hibridos en Espana. *Boletin de Sanidad Vegetal: Plagas* 27: 395–400.

Pérez Hidalgo N, Gonzales Hernandez A, Seco Fernandez MV (2000) Dos especies de Cerataphis (Hemiptera, Aphididae: Hormaphidinae) introducidas en las Islas Canarias. *Boletin de Sanidad Vegetal: Plagas* 26: 425–432.

Pérez-Hidalgo N, Nieto Nafria JM (2005) Tinocallis ulmiparvifoliae Matsumura, 1919 (Hemiptera: Aphididae, calaphidinae): une nueva especie de pulgon introducida en la peninsula ibérica. *Boletin de la Asociacion espanola de Entomologia* 29: 125–127.

Pérez Hidalgo N, Pons X, Mier Durante M (2008) Detection of Drepanaphis acerifoliae (Thomas) [Hemiptera: Aphididae: Drepanosiphinae] on sugar maple trees, Acer saccharinum, in Spain. *Boletin Sociedad Entomologica Aragonesa* 43: 441–444.

Petrović O (1998) Check-list of aphids (Homoptera :Aphididae) in Serbia. *Acta entomologica serbica* 3: 9–42.

Petrović O, Milanović S (1999) [Pterochloroides persicae Choldk. – new pest of peach in Serbia] (in Serbian). *Biljni lekar* 4: 354–356.

Petrović-Obradović O, Tomanović Ž, Poljaković-Pajnik L, Vučetić A (2007) An invasive species of aphid, *Prociphilus fraxinifolii* (Hemiptera, Aphididae, Eriosomatinae), found in Serbia. *Archives of Biological Sciences, Belgrade* 59: 9–10.

Petrović-Obradović O, Tomanović Ž, Poljaković-Pajnik L, Hrnčić S, Vučetić A, Radonjić S (2010) New Invasive Species of Aphids (Hemiptera, Aphididae) in Serbia and Montenegro. *Archives of Biological Sciences, Belgrade* (in press).

Pintera A (1987) Taxonomic revision of the species of the genus *Chaitophorus* Koch in palearctis (Homoptera: Aphidoidea). *Deutsche Entomologische zeitschrift* 34: 219–340.

Piron PGM (1987) The advance of the Americal lupin aphid (*Macrosiphum albifrons* Essig) (Homoptera: Aphididae) in Europe. *Journal of Applied Entomology* 103: 111–112.

Poljaković-Pajnik L, Petrović-Obradović O (2002) Bow-legged fir aphid *Cinara curvipes* (Patch) (Aphididae, Homoptera) new pest of *Abies concolor* in Serbia. *Acta entomologica serbica* 7: 147–150.

Poljaković-Pajnik L, Petrović-Obradović O (2009) *Chaitophorus populifolii* (Aphididae : Homoptera) new species on poplars in Serbia. In: *Proceedings International Scientific Conference Forestry in achieving millennium goals*, Novi Sad, Serbia, November 2009, 379–381.

Prior RNB (1971) Some notes on new or uncommon aphids recently found in Britain. *Zoological Journal of the Linnean Society* 50: 397–430.

Prior RNB (1974) Three Japanese aphids introduced to Britain on imported «bonsai» trees. *Plant Pathology* 23: 48.

Prior RNB (1975) Three north american aphid species recently found in Britain infesting cultivated rose, *Cupressus macrocarpa* and *Poa trivialis*. *Plant Pathology* 24:123–124.

Qiao G, Zhang GX (2004) Prelimary study of aphid diversity in China: taxonomic and geographic variation. In: Simon JC, Dedryver CA, Rispe C, Hullé M (Eds) *Aphids in a new Millenium. Proceedings of the 6th International Symposium on aphids*. Rennes, France Sept. 2001, INRA Editions, 139–146.

Quednau FW (1954) Monographie der mitteleuropäischen Callaphididae (Zierläuse (Homoptera, Aphidina)) unter besonderer Berücksichtigung des ersten Jugendstadiums. I. Die Junglarven des ersten Stadiums der mitteleuropäischen Callaphididae. *Mitteilungen der Biologischen Bundesanstalt für Land- und Forstwirtschaft* 78: 1–55.

Quednau FW (1999) Atlas of the Drepanosiphine aphids of the world. Part I.: *Panaphidini* Oestlund, 1922 - *Myzocallidina* Börner, 1942 (1930) (Hemiptera: Aphididae: Calaphidinae). *Contributions of the American Entomological Institute* 31: 1–281.

Quednau FW (2003) Atlas of the drepanosiphine aphids of the world. Part II: Panaphidini Oestlund, 1922 - Panaphidina, Oestlund 1923 (Hemiptera: Aphididae: Calaphidinae). *Memoirs of the American Entomological Institute* 72: 1–301.

Rabasse JM, Coceano PG, Barbagallo S (2005) On the presence in France and North Italy of Siphonatrophia cupressi (homoptera, Aphididae), a new aphid of North American origin living on Cupressaceae. *Bolletino de Zoologia Agraria e Bachicultura* 37: 77–83.

Rabasse JM, Drescher J, Chaubet B, Limonta L, Turpeau E, Barbagallo S (2005) On the presence in Europe of two *Illinoia* aphids of North American origin (Homoptera, Aphididae). *Bolletino di Zoologia Agraria e di Bachicoltura, serie II* 37: 151–168.

Rabitsch W, Essl F (2006) Biological invasions in Austria: patterns and case studies. *Biological Invasions* 8: 295–308.

Remaudière G (1951) Contribution à l'étude des Aphidoidea de la faune française. Description de quelques Aphididae nouveaux et addition a la liste des *Myzinae* et *Dactynotinae*. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 30: 125–144.

Remaudière G (1952) Contribution à l'étude des Aphidoidea de la faune française. Description de quelques Aphididae nouveaux et addition a la liste des *Myzinae* et *Dactynotinae*. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 31: 232–263.

Remaudière G (1954) Contribution à l'étude des Aphidoidea de la faune française (7e note). Deuxième addition a la liste des *Dactynotinae* et *Myzinae* (Hom. Aphidoidea) de la faune Française. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 30: 2125–144.

Remaudière G (1989) Découverte en France de l'espèce américaine *Myzocallis* (*Lineomyzocallis*) *walshii* (Monell) (Hom. Aphididae). *Annales de la Société Entomologique de France* 25: 117.

Remaudière G, Eastop VF, Autrique A (1985) Distribution des aphides de la region éthiopienne. In: Remaudière G (Ed) Contribution à l'écologie des aphides africains. Roma, Italy: Organisation des Nations Unies pour l'Alimentation et l'Agriculture, 77–93.

Remaudière G, Quednau FW, Heie OE (1988) Un nouveau Tinocallis sur Ulmus, originaire d'Asie Centrale et semblable à T. saltans (Nevsky (Homoptera; Aphididae). *The Canadian Entomologist* 120: 211–219.

Remaudière G (1989) Découverte en France de l'espèce américaine *Myzocallis (Lineomyzocallis) walshii* (Monell) (Hom.Aphididae). *Revue Francaise d'Entomologie*: 14: 172.

Remaudière G, Serain M, Trouve C, Demeester S (1992) Données nouvelles sur le genre *Trichosiphonaphis* Takahashi: cycles, hôtes, synonymies et distribution géographique (Homoptera, Aphididae). *Revue Française d'Entomologie* 14: 40–58.

Remaudière G, Munoz Viveros AL (1992) Sur la presence en France de *Myzus hemerocallis* Talahashi (Homoptera, Aphididae). *Revue Francaise d'Entomologie* 14: 172.

Remaudière G, Sorin M (1993) Two new aphids of the genus *Tuberocephalus* Shinji (Homoptera, Aphididae). *Japanese Journal of Entomology* 61: 683–690.

Remaudière G, Remaudière M (1997) Catalogue des Aphididae du monde - Catalogue of the world's Aphididae (Homoptera, Aphidoidea). Paris, France: INRA Editions. 437 pp.

Remaudière G, Ripka G (2003) Arrival in Europe (Budapest, Hungary) of American ash aphid, *Prociphilus (Meliarhizophagus) fraxinifolii* (Hemiptera, Aphididae, Eriosomatinae, Pemphigini). *Revue Francaise d'Entomologie* 25: 152.

Remaudière G, Sertkaya E, Ozdemir I (2003) Alert! Discovery in Turkey of the American aphid, *Aphis illinoisensis*, a grapevine pest (Hemiptera, Aphididae). *Revue Francaise d'Entomologie* 25: 170.

Ripka G (2001) New data to the knwoledge of the aphid fauna of Hungary (Homoptera: Aphidoidea). *Acta Phytopathologica et Enomologia Hungarica* 36: 81–87.

Roberti D (1975) Aspetti fitopatologici della mandorlicoltura puglirse: gli insetti. *Entomologica* 11: 9–20.

Scheurer S, Binazzi A (2004) Notes in bio-ecology and ethology of *Cinara curvipes* (Patch), a newly introduced species into Europe (Aphididae, Lachninae). *Redia* 87: 61–65.

Schouteden H (1906) catalogue des aphides de Belgique. *Mémoires de la Société Entomologique des Belgique* 12: 189–246.

Silvestri F (1939) Compendio di Entomologia applicata, VolI. Portici, Napoli, Italy: Tipografia Bellavista. 972pp.

Sousa-Silva CR, Ilharco FA (1995) *Afideos do Brazil e suas plantas hospedeiras;* Sao Carlos, Brazil: Editora da Univeridade de Sao Carlos. 85pp.

Stroyan HLG (1950) Recent additions to the British aphid fauna. Part. I. *Dactynotus* Rafinesque to *Rhopalosiphum* Koch C.L. *Transactions of the Royal Entomological Society (Lond.)* 101: 90–123.

Stroyan HLG (1954) A new subgenus and species of *Myzus* (Passerini, 1860). Proceeding *of the Royal Entomological Society* (Lond.) 23: 1–40.

Stroyan HLG (1956) More Merioneth aphid records. *The Entomologist* 89: 302–303.

Stroyan HLG (1964) Notes on hitherto unrecorded or overlooked british aphid species. *Transactions of the Royal Entomological Society* (Lond.) 116: 29–72.

Stroyan HLG (1971) *Masonaphis lambersi* MacGill: An introduced aphid pest of hybrid rhododendron. *Plant Pathology* 20: 196.

Stroyan HLG (1972) Additions and amendments to the check list of British aphids (Homoptera: Aphidoidea). *Transactions of the Royal Entomological Society* (Lond.) 124: 37–79.

Stroyan HLG (1977) *Homoptera. Aphididae (Part) Chaitophoridae, Callaphididae. Handbooks for the identification of British Insects Vol. 2 Part 4a*. London, UK : Royal Entomological Society of London. 130 pp.

Stroyan HLG (1981) A North American lupin aphid found in Britain. *Plant Pathology* 30: 253.

Stroyan HLG (1984) *Aphids – Pterocommatinae and Aphidinae, Homoptera. Aphididae. Handbooks for the identification of British Insects Vol. 2 Part 6*. London, UK: Royal Entomological Society of London. 232 pp.

Sűss L (1972–73) Reperti afidologici su alcune piante in serra nel Milanese. *Bollettino di Zoologia Agraria e di Bachicoltura ser. II* 11: 177–193.

Szelegiewicz H (1978) Przeglad systematyczny mszyc polski. Zeszyty problemowe postepow nauk rolniczych. *Polska Akademia Nauk* 208: 40pp.

Tambs-Lyche H, Heie O (1973) An Asian aphid suddenly appearing in large numbers on *Impatiens parviflora* in Europe. *Entomologiske Meddelelser* 41: 167–173.

Tashev D (1961) Novi listni vushki (Homoptera, Aphididae) za faunata na Bulgaria, godishnik na SU, biologo-geologo-geografski fakultet. *1-biologia* 1958/1959, 53: 157–162.

Tashev D (1964) Novi za faunata na Bulgaria listni bushki (Homoptera Aphididae), godishnik na SU biologo-geologo-geografski fakultet. *1-biologia* 1961/1962, 56: 179–190.

Tashev D (1982) A list of the aphids from Bulgaria. *Annuaire de Universite de Sofia "Kliment Ohridski" Faculte de Biologie; Livre 1 – Zoologie*: 20–35.

Tavares JS (1900) As zoocecidias Portuguesas. *Anais das Ciencias Naturaes* 7: 15–108.

Tavares JS (1905) Synopse das zoocecidias portuguesa. *Broteria* 4: 1–123.

Taylor LR, Palmer JMP (1972) Aerial sampling. In: Van Emdem HF (Ed) *Aphid Technology*. London, UK: Academic Press, 189–234.

Theobald FV (1912) A new strawberry *Aphis*. *The Entomologist* 45: 223.

Theobald FV (1913) The British species of the genus Macrosiphum pass. *Journal of Economical biology* 8: 47–94.

Theobald FV (1918) Notes on new and little known british aphides IV. *The Entomologist* 51:25–29.

Theobald FV (1926) *The plant lice or Aphididae of Great Britain, Vol I.*, London, UK: headley Brothers. 372pp.

Theobald FV (1927) *The plant lice or Aphididae of Great Britain, Vol 2.*, London, UK: headley Brothers. 411pp.

Theobald FV (1929) *The plant lice or Aphididae of Great Britain 3*. London, UK: Headley Brothers. 364 pp.

Tschorbadjiev P (1924) Konstatirani vredni nasekomi i drugi zivotinski nepriyateli po kulturnite rasteniya w Bulgaria prez 1923 g. *Svedeniya po zemedelieto* 5: 2–26.

Tsitsipis JA, Angelakis E, Margaritopoulos JT, Tsamandani K, Zarpas KD (2005) First record of the grapevine aphid *Aphis illinoisensis* in the island of Kriti, Greece. *Bulletin OEPP/EPPO* 35: 541–542.

Tsitsipis JA, Katis N, Margaritopoulos J, Lykouressis D, Avgelis A, Gargalianou I, Zarpas K, Perdikis D, Papapanayotou A (2007) A contribution to the aphid fauna of Greece. *Bulletin of Insectology* 60: 31–38.

Turpeau E, Remaudière G (1990) Découverte en France d'un puceron des pins américains du genre *Essigella* (Hom. Aphididae). *Comptes-Rendus de l'Académie d'Agriculture de France* 76: 131–132.

Van Harten A (1982) Lista anotada dos afideos (Homoptera: Aphidoidea) conhecidos das Ilhas de cabo Verde. *Agronomia lusitana* 41: 313–321.

Van Harten A, Coceano GG (1981) On some interesting species (Hemiptera Aphidoidea) trapped in Udine Province, Italy. *Bollettino del Labratorio di Entomologia Agraria "Filippo Silvestri" in Portici* 38: 29–51.

Vasilev IV (1910) Brachcevaja, ili tykvennaja tlja (*Aphis gossypii* Glover). *Trudy Byuro Entomologii* 8: 1–24.

Velimirovic V (1976) A new pest in yugoslavia *Pterochloroides persicae* (Homoptera. Aphididae) on peach trees. *Zastita Bilja* 27: 29–35.
Walker F (1848) Descriptions of aphids (2). *Annals and magazine of natural History* 1: 443–454.
Walker F (1849) Descriptions of new British aphides. *Zoologist* 7: xxxi-xl.
Ward PH (1961) A note on an aphid new to Europe. *Entomologist's Gazette* 12: 116.

Table 9.1.1. List and main characteristics of Aphididae species alien *to* Europe. Status: A: Alien *to* Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update February 2010.

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Acyrthosiphon Acyrthosiphon caraganae Cholodkovsky 1908	A	phyto-phagous	Asia-Temperate	1907, RU	AL, AT, BG, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IT, IT-SIC, LT, LV, MK, NO, NL, NO, PL, RO, RS, RU, SE, SI, SK, UA	F, I2	*Caragana.* other Fabaceae	Cholodkovsky (1907), Hržič (1996), Mordvilko (1914), Petrović (1998), Remaudière (1951), Tashev (1982)
Acyrthosiphon Acyrthosiphon kondoi Shinji, 1938	A	phyto-phagous	Asia-Temperate	< 2004, FR-COR	FR-COR, GR	E, I1	*Medicago*	Eastop (1971), Nieto Nafria e al. (2007), Tsitsipis et al. (2007)
Acyrthosiphon Acyrthosiphon primulae Theoblad 1913	A	phyto-phagous	Asia-Temperate	1913, GB	BG, CH, CZ, DK, ES, FR, DE, GB, GR, IE, IT, IT-SIC, NL, PT, SE, SK	I2, J100	*Primula*	Heie (1994), Remaudière (1952), Theobald (1913), Tsitsipis et al. (2007)
Aloephagus myersi Essig, 1950	A	phyto-phagous	Africa	1937, GB	ES, FR, GB, GR, IT, IT-SIC	I2, J100	*Aloe, Haworthia, Gasteria*	Eastop (1956), Leclant (1978), Micieli De Biase (1988), Tsitsipis et al. (2007)
Aphis Aphis forbesi Weed, 1889	A	phyto-phagous	North America	1928, FR	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, FR, HR, HU, IT, LV, MD, PL, RO, RS, SK	I1, J100	*Fragaria*	Balachowsky (1933), Heie (1986), Paillot (1928)
Aphis Aphis gossypii Glover 1877	A	phyto-phagous	Tropical, sub-tropical	<1758 Unknown	AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, HR, HU, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, MK, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SK, UA	I2, I1, J100, E, F	Polyphagous (mainly Cucurbi-taceae, Rutaceae and Malvaceae)	Blackman and Eastop (2006), Buckton (1879), Theobald (1927), Tschorbadjiev (1924), Vasilev (1910)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Aphis Aphis illinoisensis Shimer 1866	A	phyto-phagous	North America	2005, GR-CRE	GR-CRE, ME	FB	*Vitis*	Petrović-Obradović et al. (in press), Tsitsipis et al. (2005)
Aphis Aphis spiraecola Patch, 1914	A	phyto-phagous	Asia-Temperate	1961, PT	AT, BG, CH, DE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, HR, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, RS, UA	E, I2, FA, FB, G	Polyphagous (*Citrus*, apple, *Spiraea*)	Blackman and Eastop (2000), Blackman and Eastop (2007), Ilharco (1968b)
Aphis Aphis spiraephaga F.P. Müller, 1961	A	phyto-phagous	Asia-Temperate	1955, CZ	AL, AT, CH, CZ, DE, DK, ES, FI, FR, HR, HU, IT-SIC, LT, LV, MD, MK, PL, PT, RO, RU, SE, SI, SK, UA	I2	*Spiraea*	Heie (1986), Holman (1971), Ilharco (1968b), Ilharco (1973), Tashev (1964)
Aphis Aphis spiraephila Patch, 1914	A	phyto-phagous	North America	1955 UA	UA	I2	*Spiraea*	Holman (1971), Nieto Nafria et al. (2007)
Aphis Bursaphis oenotherae oenotherae Oestlund 1887	A	phyto-phagous	North America	1972, DE	FR, DE, GB, IT-SIC, PL, RS	G3, I2	*Oenothera*	Barbagallo (1994), Műller (1974)
Aphis catalpae Mamontova, 1953	A	phyto-phagous	Asia	0	HU, UA	I2	*Catalpa*	Mamontova (1955), Petrović-Obradović et al. (in press), Ripka (2001)
Appendiseta robiniae (Gillette, 1907)	A	phyto-phagous	North America	1978, IT	BE, BG, CH, CZ, DE, ES, ES-BAL, FR, FR-COR, GB, GR, HR, HU, IT, IT-SIC, NL, RS, SK	I2, G5	*Robinia*	Arzone and Vidano (1990), Lampel (1983), Leclant and Remaudière (1986), Micieli De Biase and Calambuca (1979), Pati and Tomatore (1988), Petrović (1998)
Brachycaudus Mordvilkomemor rumexicolens (Patch, 1917)	A	phyto-phagous	North America	1953, GB	BE, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, IT, IT-SAR, IT-SIC, MK, NL, NO, PL, PT, PT-MAD, RO, RU, SE, SK, UA	H5, I1	*Rumex;* other Polygonaceae	Barbagallo (1994), Barbagallo and Stroyan (1982), Heie (1973), Holman (1965), Ilharco (1974), Stroyan (1956)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Cerataphis brasiliensis (Hempel, 1901)	A	phyto-phagous	Asia-Tropical	1981, PT-MAD	ES-CAN, FR, PT-MAD	I2, J100	Palms	Chapin and Germain (2005), Germain and Chapin (2004), Ilharco (1984), Pérez Hidalgo et al. (2000)
Cerataphis lataniae (Boisduval, 1867)	A	phyto-phagous	Asia-tropical	1867, FR	CZ, ES-CAN, DE, FR, GB, IT, PL	I2, J100	*Areca, Musa*	Boisduval (1867), Chapin and Germain (2005), Pérez Hidalgo et al. (2000)
Cerataphis orchidearum (Westwood, 1879)	A	phyto-phagous	Asia-Tropical	1906, BE	BE, ES, FI, FR, GB, HU, PT-MAD, RU, SE	J100	Orchids	Germain and Chapin (2004), Heie (1980), Ilharco (1973), Ilharco (1974), Schouteden (1906)
Chaetosiphon Pentatrichopus fragaefolii (Cockerell, 1901)	A	phyto-phagous	North America	1912, GB	AT, BE, BG, CH, CZ, ES, ES-CAN, FR, DE, GB, HR, HU, IE, IL, IT-SIC, IT, LV, MK, NL, NO, PT, PT-AZO, PT-MAD, RO, RS, SI	I1, J100	*Fragaria*	Balachowsky (1933), Theobald (1912)
Chaitophorus populifolii (Essig, 1912)	A	phyto-phagous	North America	1956, DE	DE, RS	I2	*Populus*	Pintera (1987), Poljaković-Pajnik and Petrović-Obradović (2009)
Chaitophorus saliapterus quinquemaculatus Bozhko 1976	A	phyto-phagous	Asia	1953,UA	IT, UA	F9	*Salix*	Binazzi and Barbagallo (1991), Bozhko (1976), Pintera (1987)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Chromaphis juglandicola (Kaltenbach, 1843)	A	phyto-phagous	Asia-Temperate	< 1758 Unknown	AT, BE, BG, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, HR, HU, IL, IT, IT-SAR, IT-SIC, MD, MK, PL, PT-AZO, PT-MAD, PT, RO, RS, SE, SI, SK, UA	I2, G5	*Juglans*	Balachowsky and Mesnil (1935), Heie (1982), Kaltenbach (1843), Schouteden (1906), Theobald (1927)
Cinara Cedrobium laportei (Remaudière, 1954)	A	phyto-phagous	Africa	1967, FR	ES, FR, GB, IT, IT-SAR, IT-SIC, NL, PT, SI	G3, G5, I2	*Cedrus*	Covassi (1971), Emonnot et al. (1967), Leclant (1978)
Cinara Cinara cedri Mimeur, 1936	A	phyto-phagous	Africa	1974,IT	BE, CH, DK, ES, FR, GB, HR, HU, IL, IT, IT-SAR, IT-SIC, RS, SI	I2, G5	*Cedrus.*	Covassi and Binazzi (1974), Fabre (1976)
Cinara Cinara curvipes (Patch, 1912)	A	phyto-phagous	North America	1999, GB	CZ, CH, DE, GB, RS, SK, SL	I2	*Abies*	Angst et al. (2007), Jurc et al. (2009), Martin (2000), Poljaković-Pajnik and Petrović-Obradović (2002), Scheurer and Binazzi (2004)
Drepanaphis acerifoliae (Thomas, 1878)	A	phyto-phagous	North America	1992, IT	IT , ES	I2	*Acer*	Lozzia and Binaghi (1992), Pérez Hidalgo et al. (2008)
Ericaphis scammelli Mason 1940	A	phyto-phagous	North America	1964, GB	FR, GB, IT, NL	I1, I2	*Vaccinium*	Barbagallo et al. (1999), Barbagallo et al. (1998), Prior (1971)
Ericaphis wakibae (Hottes, 1934)	A	phyto-phagous	North America	1963, GB	CZ, GB	I1, B3	*Fragaria*	Stroyan (1972)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Eriosoma lanigerum (Hausmann, 1802)	A	phyto-phagous	North America	1787, GB	AL, AT, BE, BG, CH, CY, CZ, DE, DK, ES, ES-CAN, FR, DE, GB, GR, HR, HU, IE, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SE, SI, SK, UA	I, I1	*Malus*; orchard trees	Balachowsky and Mesnil (1935), Marchal (1928)
Essigella Essigella californica (Essig, 1909)	A	phyto-phagous	North America	1988, FR	ES,FR, IT, IT-SAR, IT-SIC, PT-MAD	G5, I2	*Pinus radiata, P. pinaster*	Aguiar and Ilharco (2001), Turpeau and Remaudière (1990)
Greenidea Greenidea ficicola Takahashi 1921	A	phyto-phagous	Asia-Tropical	2004, IT	ES, IT, IT-SIC	I2	*Ficus*	Barbagallo et al. (2005a), Mifsud (1998)
Hysteroneura setariae (Thomas, 1878)	A	phyto-phagous	North America	1982, PT-MAD	ES, PT-MAD	E, I	*Prunus*, fruit trees, Graminae	Blackman and Eastop (2006), Meliá Masiá (1995), Van Harten (1982)
Idiopterus nephrelepidis Davis, 1909	A	phyto-phagous	Tropical, sub-tropical	1915, GB	BE, CH, CZ, DE, DK, ES, ES-CAN, FR, GB, GR, IE, IL, IT, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, PT, RU, SE, SI, SK	I2, J1, J100	Tropical ferns indoors	Heie (1994), Laing (1923), Theobald (1926), Tsitsipis et al. (2007)
Illinoia Illinoia andromedae (MacGillivray, 1958)]	A	phyto-phagous	North America	1960, GB	GB	I2	Asteraceae	Eastop (1962), Stroyan (1964)
Illinoia Illinoia azaleae Mason, 1925	A	phyto-phagous	North America	1950, GB	AT, CH, CZ, DK, ES, FI, FR, DE, GB, HU, IT, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, SI	I2, J100	*Rhododendron*; Ericaceae	Biurrun and Nieto Nafría (1987), Heie (1995), Ilharco (1968b), Stroyan (1950)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Illinoia Illinoia goldamaryae (Knowlton, 1938)	A	phyto-phagous	North America	1960, GB	GB	I2, J100	Astereacae (*Aster, Erigero., Solidago*)	Eastop (1962), Stroyan (1964), Ward (1961)
Illinoia Illinoia liriodendri (Monell, 1879)	A	phyto-phagous	North America	1998, FR	DE, FR, GB, IT, SI	G5, I2	*Liriodendron*	Limonta (2001), Rabasse et al. (2005b)
Illinoia Illinoia morrisoni (Swain, 1918)	A	phyto-phagous	North America	1960, GB	FR, GB	I2	*Cupressus*	Eastop (1962), Prior (1975), Rabasse et al. (2005b) Stroyan (1964)
Illinoia Masonaphis lambersi (MacGillivray, 1960)	A	phyto-phagous	North America	1971, NL	BE, CH, CZ, DK, GB, NL, NO, PT-MAD, SK	I2	*Rhododendron, Kalmia*	Aguiar and Ilharco (2001), Heie (1995), Hille Ris Lambers (1973), Stroyan (1971), Stroyan (1972)
Illinoia Masonaphis rhododendri (Wilson, 1918)]	A	phyto-phagous	North America	1939, GB	GB, NL, SK	I2, J100	*Rhododendron*	Eastop (1956), Heie (1994), Stroyan (1950)
Impatientinum Impatientinum asiaticum Nevsky 1929	A	phyto-phagous	Asia-Temperate	1967, RU	AT, CH, CZ, DE, DK, EE, FI, FR, GB, LV, PL, RO, RU, SE, SI, SK	G, I2, X25	*Impatiens*	Heie (1994), Holman (1971), Ilharco (1968b), Tambs-Lyche and Heie (1973)
Iziphya flabella (Sanborn, 1904)	A	phyto-phagous	North America	1954, DE	DE, UA	I2	*Carex*	Quednau (1954)
Macrosiphoniella Macrosiphoniella sanborni (Gillette, 1908)	A	phyto-phagous	Asia-Temperate	1907, PT	AL, AT, BE, BG, CH, CY, CZ, DK, ES, ES-CAN, FI, FR, DE, GB, GR, HR, IE, IL, IT, IT-SIC, LT, LV, MD, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU,SE, UA	I2, J100	*Chrysan-themum*	Balachowsky and Mesnil (1935), Del Guercio (1911), Del Guercio (1913), Holman (2009), Ilharco (1968b), Ilharco (1974), Theobald (1926)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Macrosiphum Macrosiphum albifrons Essig, 1911	A	phyto-phagous	North America	1981, GB	AT, BE, CH, DE, FR, GB, GR, IE, IT, IT-SIC, SE	I1, I2	*Lupinus, Fragaria*	Carter et al. (1984), Hullé et al. (1998), Meier and Schweizer (1987), Piron (1987), Stroyan (1981)
Macrosiphum Macrosiphum euphorbiae (Thomas, 1878)	A	phyto-phagous	North America	1917, GB	AL, AT, BE, BG, CH, CZ, DK, EE, ES, ES-CAN, FI, FR, FR-COR, DE, GB, GR, HR, HU, IS, IE, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, MK, MT, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	E, F, I, J, J100	Polyphagous (vegetables, *Fragaria*)	Blackman and Eastop (2000), Eastop (1958)
Macrosiphum Macrosiphum ptericolens Patch, 1919	A	phyto-phagous	North America	1972, GB	GB, PL	G	*Pteridium aquilinum* (bracken)	Holman (2009), Lawton and Eastop (1975)
Megoura lespedezae (Essig & Kuwana, 1918)	A	phyto-phagous	Asia-Temperate	1994, CH	CH	I1	Polyphagous (vegetables; *Lespedeza*, Japanese clover)	Giacalone and Lampel (1996)
Melanaphis bambusae (Fullaway, 1910)	A	phyto-phagous	Asia-Temperate	1961, IT	ES, FR, GR, IT-SIC, IT, PT, PT-MAD, RS	I2	*Bambusa*	Hille Ris Lambers (1966), Nieto Nafria et al. (2007)
Melaphis rhois (Fitch, 1866)	A	phyto-phagous	North America	1902, GB	GB, SE	I2	*Rhus*	Blackman and Eastop (1994), Theobald (1918), Theobald (1929)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Monellia caryella (Fitch, 1855)	A	phyto-phagous	North America	1985, ES	IL, ES	G5	*Juglans, Carya*	Hermoso de Mendoza (1988), Nieto Nafría and Mier Durante (1998)
Monelliopsis caryae (Monell ex Riley & Monell, 1879)	A	phyto-phagous	North America	1984, FR	ES, FR, HU, IL, IT, PT	G5	*Juglans, Carya*	Hullé et al. (1998), Mier Durante and Pérez Hidalgo (2002)
Monelliopsis pecanis Bissell, 1983	A	phyto-phagous	North America	1995, PT-MAD	IT-SIC, PT-MAD	G5	*Carya*	Aguiar and Ilharco (1997), Barbagallo and Suma (1999)
Myzaphis turanica Nevsky, 1929	C	phyto-phagous	Crypto-genic	1976, ES	ES,FR, GB, IT-SIC, SE	I2	*Rosa rugosa*	Meliá Masiá (1998), Patti (1983)
Myzocallis Lineomyzocallis walshii (Monell ex Riley & Monell, 1879)	A	phyto-phagous	North America	1988, FR	BE, CH, CZ, DE, ES, FR, HU, IT, IT-SIC, RS	G, I2	*Quercus rubra*	Hullé et al. (1998), Petrović-Obradović et al. (2007), Remaudière (1989)
Myzus Myzus hemerocallis Takahashi, 1921	A	phyto-phagous	Asia-Temperate	1990, FR	FR, PT-MAD	I2	*Hemerocallis*	Aguiar and Ilharco (1997), Remaudière and Munoz Viveros (1992)
Myzus Myzus ornatus Laing, 1932	A	phyto-phagous	Asia-Temperate	1932 GB	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, FR-COR, GB, GR, HR, HU, IE, IT, IT-SAR, IT-SIC, LV, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK	I, J100, X8	Polyphagous (*Prunus cornuta*-primary host); many herbaceous plants and vegetables-secondary host)	Blackman and Eastop (2000), Ilharco (1969), Laing (1932)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Myzus Myzus varians Davidson, 1912	A	phyto-phagous	Asia-Temperate	1946, CH	AL, AT, BA, BE, BG, CH, CZ, DE, ES, FR, FR-COR, MK, DE, GB, GR, HR, HU, IT, IT-SIC, PL, RO, RS, RU, SI, SK	I2, G5	*Prunus persicae, Clematis*	Blackman and Eastop (2000), Börner (1952), Hille Ris Lambers (1947)
Myzus Nectarosiphon ascalonicus Doncaster, 1946	A	phyto-phagous	Asia-Temperate	1941, GB	AL, AT, BE, BG, CH, CZ, DE, DK, ES, ES-CAN, FI, FR, MK, DE, GB, GR, HR, IE, IS, IT, LT, LV, NL, NO, PL, PT, PT-AZO, RO, RS, RU, SE, SK	I2, E	*Fragaria, Allium*	Börner (1952), Doncaster (1946)
Myzus Nectarosiphon persicae Sulzer 1776	C	phyto-phagous	Crypto-genic	<1758 Unknown	AL, AT, BE, BG, CH, CY, CZ, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, MK, DE, GB, GR, GR-CRE, HR, HU, IE, IT, IT-SAR, IT-SIC, LT, LV, ME, MD, MT, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SE, SI, SK, UA	G5	Polyphagous	Balachowsky and Mesnil (1935), Blackman and Eastop (2000), Boisduval (1867), Buckton (1876), Koch (1855), Macchiati (1883), Schouteden (1906), Theobald (1926)
Myzus Sciamyzus cymbalariae Stroyan, 1954	C	phyto-phagous	Crypto-genic	1950, GB	BE, CH, CZ, DE, ES, FR, GB, GR, IT, PT-AZO, PT-MAD	I	Polyphagous	Blackman and Eastop (2000), Ilharco (1974), Stroyan (1954)
Nearctaphis bakeri (Cowen ex Gillette & Baker, 1895)	A	phyto-phagous	North America	1964,FR	AL, CH, ES, ES-BAL, FR, DE, GB, GR, IT, IT-SIC, PT, PT-AZO, SK UA	I, E	Maloideae (primary hosts) and Fabaceae (secondary hosts; e.g. *Trifolium*)	Heie (1992), Leclant (1967), Stroyan (1972)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Neomyzus circumflexus Buckton 1876	A	phyto-phagous	Asia	1876, GB	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, FR-COR, GB, HR, HU, IE, IT, IT-SIC, LT, LV, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, UA	I2, J100	Polyphagous flower crops	Blackman and Eastop (2000), Buckton (1876), Ilharco (1969)
Neophyllaphis podocarpi Takahashi, 1920	A	phyto-phagous	Asia-Temperate	1990, IT	IT	I2	*Podocarpus*	Limonta (2001)
Neotoxoptera formosana (Takahashi, 1921)	A	phyto-phagous	Asia	1994, FI	DE, FI, FR, GB, IT, NL, PT-MAD	I1, J1, J100	*Allium*	Aguiar and Ilharco (2001), Barbagallo Ciampolini (2000), Blackman and Eastop (2000)
Neotoxoptera oliveri (Essig, 1935)	A	phyto-phagous	Asia-Temperate	1959, PT	ES, FR, IT-SIC, PT-MAD, PT, RS	I1, J100	*Viola, Allium*	Ilharco (1960), Ilharco (1968b)
Neotoxoptera violae (Pergande, 1900)	A	phyto-phagous	Asia-Temperate	1939, IT	ES, ES-CAN, FR, IT IT-SIC	I2	*Viola*	Barbagallo and Coccuzza (1998), Germain and Deogratias (2008) Silvestri (1939)
Panaphis juglandis (Goeze, 1778)	A	phyto-phagous	Asia	<1758 unknown	AL, AT, BE, BA, BG, CH, CZ, DK, ES, ES-CAN, FR, FR-COR, DK, GB, GR, HR, HU, IL, IT-SIC, IT, MD, PL, PT, RO, RS, SE, SI, SK, UA	I2, G5	*Juglans*	Blanchard (1840), Goeze (1778), Ilharco (1968a), Kaltenbach (1843), Malkov (1908), Schouteden (1906), Walker (1848)
Paoliella eastopi Hille Ris Lambers, 1973	A	phyto-phagous	Africa	<2004, GB	GB	U	Passionfruit in native range (Kenya)	Nieto Nafria et al. (2007)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Pemphigus Pemphigus populitransversus Riley ex Riley & Monell, 1879	A	phyto-phagous	North America	1966, PT-MAD	GB, PT-AZO, PT-MAD	I2, F	*Populus*	Blackman and Eastop (1994), Ilharco (1974)
Pentalonia nigronervosa Coquerel, 1859	A	phyto-phagous	Tropical, subt-ropical	1922, GB	DK, DE, GB, IL, IT, NL, PT-AZO, ES-CAN	J100	*Musa* (preferred); Poly-phagous on tropical and subtropical ornamental plants	Cairaschi (1942), Sűss (1972–73)
Periphyllus californiensis (Shinji, 1917)	A	phyto-phagous	Asia-Temperate	1932, GB	HR, DK, DE, GB, IT, NL, CH	I2, G5	*Acer*	Blackman and Eastop (1994), Doncaster (1954), Eastop (1956),
Prociphilus Meliarhizophagus fraxinifolii Riley ex Riley & Monell, 1879	A	phyto-phagous	North America	2003, HU	BG, HU, RS	G, G5	*Fraxinus*	Petrović-Obradović et al. (2007), Remaudière and Ripka (2003)
Pterochloroides persicae (Cholodkovsky, 1899)	A	phyto-phagous	Asia-Temperate	1975, IT	AL, BG, CY, ES, FR, GR, IT, IT-SIC, RO, RS, UA	I2, G5	*Prunus*; fruit trees (peach)	Ciampolini and Martelli (1977), Petrović and Milanović (1999), Roberti (1975), Velimirovic (1976)
Pterocomma pseudopopuleum Palmer, 1952	A	phyto-phagous	North America	<2004, UA	EE, UA	G	Populus	Nieto Nafria et al. (2007)
Reticulaphis distylii vand der Goot 1917	A	phyto-phagous	Asia-Temperate	1998, PT	ES, PT	I2, G5	Ficus	Barbagallo et al. (2005b)
Rhodobium porosum (Sanderson, 1900)	A	phyto-phagous	Tropical, sub-tropical	1934, ES	AL, AT, BA, BG, CH, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, GR, HU, IL, IT, IT-SIC, LV, NL, PL, PT, PT-MAD, RO, RS, SE, SI, SK	I2, J100	*Fragaria, Rosa* (in greenhouses in Central Europe)	Ilharco (1969), Mimeur (1936), Tashev (1964)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Rhopalosiphoninus Rhopalosiphoninus latysiphon (Davidson, 1912)	A	phyto-phagous	North America	1921, IT	AL, AT, BE, BG, CH, CZ, DE, ES, FR, GB, GR, HR, IT, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, RO, RU	I1	*Solanum;* polyphagous on vegetables (*Beta, Fragaria, Ipomea*) and flowers (*Gladiolus*)	Blackman and Eastop (2000), Remaudière (1952), Tashev (1961)
Rhopalosiphum insertum (Walker, 1849)	A	phyto-phagous	North America	1848 GB	AL, AT, BY, BE, BG, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, YU, FR, FR-COR, DE, GB, GR, HU, IE, IT, LT, LV, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SE, SI, SK, UA	I1, E	Graminae (*Poa, Festuca, Juncus*)	Blackman and Eastop (2000), Dospevski (1910), Ilharco (1968a), Walker (1849)
Rhopalosiphum maidis (Fitch, 1856)	A	phyto-phagous	Asia	1903, IT	AL, BE, BG, CH, CY, CZ, DE, DK, ES, ES-CAN, FI, ,FR, FR-COR, GB, GR, GR-CRE, HU, IT-SAR, IT-SIC, IT, LV, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, ES, SK, UA	I1, E	Maize, sorghum; other crops	Blackman and Eastop (2000), Del Guercio (1913), Del Guercio (1917), Dospevski (1910), Eastop (1956), Heie (1986), Ilharco (1961)
Rhopalosiphum rufiabdominale (Sasaki, 1899)	A	phyto-phagous	Asia-Temperate	1960 PT	BG, DK, ES, FI, FR, GR, IT, IT-SIC, PT, PT-AZO, PT-MAD, RU, UA	I1	Rice roots, Gramineae	Blackman and Eastop (2006), Heie (1986), Ilharco (1968a), Ilharco (1973)
Sipha Sipha flava (Forbes, 1884)	A	phyto-phagous	North America	1979, PT-AZO	AL, PT-AZO	I1	Sugarcane	Sousa-Silva and Ilharco (1995)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Siphonatrophia cupressi Swain, 1918	A	phyto-phagous	North America	1999, FR	FR, IT	G5, I2, FA	*Cupressus*	Rabasse et al. (2005a)
Sitobion Sitobion alopecuri (Takahashi, 1921)	A	phyto-phagous	Asia-Temperate	<2004, GB	GB, NL	I2, E	Graminae	Blackman and Eastop (2006), Nieto Nafria ei al. (2007)
Sitobion Sitobion luteum (Buckton, 1876)	C	phyto-phagous	Crypto-genic	1875 GB	BE, DE, FR, GB, PT-MAD	J100	Orchidaceae, Bromeliaceae, Araceae	Blackman and Eastop (2006), Buckton (1876), Del Guercio (1911) Schouteden (1906)
Stomaphis mordvilkoi Hille Ris Lambers, 1933	A	phyto-phagous	Asia-Tropical	1980, IT	IT	G	*Juglans*	Colombo (1981)
Takecallis arundicolens (Clarke, 1903)	A	phyto-phagous	Asia-Temperate	1923, GB	CH, DE, ES, FR, GB, IE, IT, PT	I2	Bamboos	Hille Ris Lambers (1947), Ilharco (1969), Laing (1923), Stroyan (1964), Stroyan (1977), Theobald (1927)
Takecallis arundinariae (Essig, 1917)	A	phyto-phagous	Asia-Temperate	1961, GB	CH, DE, ES, GB, GR, IT, IT-SIC, PT-MAD	I2	Bamboos	Giacalone and Lampel (1996), Pati and Tomatore (1988), Stroyan (1964), Stroyan (1977)
Takecallis taiwana (Takahashi, 1926)	A	phyto-phagous	Asia-Temperate	1923, GB	CH, DE, ES, FR, GB, HR, IT, IT-SIC	I2	Bamboos (*Phyllostachys*)	Giacalone and Lampel (1996), Limonta (1990), Stroyan (1964)
Tinocallis Sappocallis nevskyi Remaudière, Quednau & Heie, 1988	A	phyto-phagous	Asia-Temperate	1978, PL	AT, BE, CH, CZ, DE, DK, FI, GB, HU, IT, NL, PL, SE	G, G5, I2, FA	*Ulmus*	Remaudière et al. (1988), Szelegiewicz (1978), Van Harten and Coceano (1981)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Tinocallis Sappocallis saltans (Nevsky, 1929)	A	phyto-phagous	Asia-Temperate	1976,RO	ES, FR, HU, IT, IT-SIC, MD, NL, PL, RO, RU, UA	G, G5, I2	*Ulmus*	Holman and Pintera (1981), Hullé et al. (1998), Remaudière et al. (1988), Van Harten and Coceano (1981)
Tinocallis Sappocallis takachihoensis Higuchi 1972	A	phyto-phagous	Asia-Temperate	1985, FR	ES, FR, IT, IT-SIC	G, G5, I2	*Ulmus*	Hullé et al. (1998), Leclant and Renoust (1986), Leclant and Remaudière (1986)
Tinocallis Sarucallis kahawaluokalani (Kirkaldy, 1906)	A	phyto-phagous	Asia-Temperate	1984, IT	DE, ES, FR, GR, IT, IT-SIC, ME	I2, G5	*Lagerstroemia indica*	Arzone and Vidano (1990), Leclant and Renoust (1986), Ossiannilsson (1959), Pati (1984), Petrović-Obradović et al. (in press)
Tinocallis Tinocallis ulmiparvifoliae Matsumura, 1919	A	phyto-phagous	Asia-Temperate	1973, GB	ES, GB, IT	I2, J100	*Ulmus*	Lucchi and Pollini (1995), Pérez Hidalgo and Nieto Nafria (2005), Prior (1971), Stroyan (1977)
Tinocallis Tinocallis zelkowae (Takahashi, 1919)	A	phyto-phagous	Asia-Temperate	1973, GB	FR, GB	I2, J100	*Zelkova*	Prior (1971), Stroyan (1977)
Toxoptera aurantii Boyer de Fonscolombe 1841	A	phyto-phagous	Tropical, sub-tropical	1841 FR	AL, BE, CH, CY, DE, ES, ES-BAL, FR, FR-COR, GB, GR, HR, IL, IT, IT-SAR, IT-SIC, ME, MT, PT-AZO, PT-MAD, PT, RO	I, G5, J100	Polyphagous (mainly *Citrus*)	Boyer de Foscolombe (1841), Del Guercio (1917), Passerini (1861), Stroyan (1984), Tavares (1900)

Species	Status	Feeding Regime	Native range	1st record in invaded areas	Invaded countries	Habitat	Hosts	References
Toxoptera citricidus Kirkaldy 1906	A	phyto-phagous	Tropical, sub-tropical	1994, PT-MAD	ES, PT, PT-MAD	I, G5	*Citrus*	Aguiar et al. (1994), Ilharco et al. (2005)
Trichosiphonaphis Xenomyzus polygonifoliae (Shinji, 1944)	A	phyto-phagous	Asia-Temperate	1990, FR	FR, GB, HU, IT, RS, UA	I2	*Lonicera, Polygonum*	Coceano and Petrovic-Obradovic (2006), Petrović-Obradović et al. (in press), Remaudière et al. (1992)
Tuberculatus Nippocallis kuricola (Matsumura, 1917)	A	phyto-phagous	Asia-Temperate	1981, PT-MAD	ES, PT, PT-AZO, PT-MAD	G1, I2	*Castanea, Quercus*	Ilharco (1984), Pedro Mansilla et al. (2001)
Uroleucon Lambersius erigeronense (Thomas, 1878)	A	phyto-phagous	North America	1952, FR	AT, BE, CH, CZ, DE, DK, ES, FI, FR, GB, GR, HU, IT, IT-SIC, LV, MD, NL, PL, PT-MAD, RO, RS, SE, SI, RK	J, J6	Asteraceae (*Erigeron, Coniza*)	Blackman and Eastop (2006), Heie (1995), Remaudière (1954)
Uroleucon Uroleucon pseudoambrosiae (Olive, 1963)	A	phyto-phagous	North America	<2004	PL	I	Asteraceae (Mainly *Lactuca* spp.)	Blackman and Eastop (2000), Blackman and Eastop (2006), Nieto Nafria et al. (2007)
Utamphorophora humboldti (Essig, 1941)	A	phyto-phagous	North America	1974, GB	FR, GB, GR, IE	I2	*Physocarpus*, Poaceae	Hullé et al. (1998), Prior (1975), Tsitsipis et al. (2007)
Wahlgreniella arbuti (Davidson, 1910)	A	phyto-phagous	North America	1905, PT	ES, ES-BAL, FR, FR-COR, GB, GR, IT, IT-SAR, IT-SIC, NL, PT, PT-MAD	I2, F6	*Arbutus, Arctostaphylos*	Heie (1995), Ilharco (1969), Tavares (1905), Tsitsipis et al. (2007)
Wahlgreniella nervata (Gillette, 1908)	A	phyto-phagous	North America	1973, GB	AT, BE, ES, ES-CAN, FR, GB, GR, IT-SIC	I2	*Rosa*	Blackman and Eastop (2006), Prior (1975), Tsitsipis et al. (2007)

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Scales (Hemiptera, Superfamily Coccoidea) Chapter 9.3

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Abstract

Scale insects are frequent invaders. With 129 established species, they numerically represent one of the major group of insects alien *to* Europe. Scales are usually small insects with wingless females. Due to this small size and concealment, many species, mainly belonging to the families Diaspididae, Pseudococcidae and Pseudococcidae, have been accidentally introduced to Europe, mostly originating from tropical regions and essentially from Asia. The trade of fruit trees and ornamentals appears to be the usual pathway of introduction. At present, alien scales represent an important component of the European entomofauna, accounting for about 30% of the total scale fauna.

Keywords

Europe, Alien, scale insects

9.3.1 Introduction

Coccoidea or scale insects is a large superfamily in the order Hemiptera with a worldwide distribution. They are unusually small insects, highly specialized for plant parasitism, that have evolved different kinds of metamorphosis depending on sex and family. Scale insects are characterized by sexual dimorphism: females are wingless, usually small (from 0.5 – 10mm), with an oval or round but flat to fairly convex body form, sometimes bud shaped, and often protected by waxy secretions or covers. The adult females may exhibit reduction or loss of appendages, depending on family and instar, and are often sedentary or sessile. Adult males are usually winged and inconspicuous, do not feed and live a few days. Scale insect identification is mainly based upon the morphology of adult females that persist on the host plant longer than the other stages.

Females usually take three or four developmental stages to reach maturity, males usually five. Parthenogenesis is quite common. Eggs are usually laid under the female body, under the scale cover, or in waxy egg-sacs. Dispersal is carried out by first instars.

Scale insects feed on various parts of the host plant (leaves, fruits, stems, branches and roots) and are frequently introduced and acclimatized in different parts of the world. This is due to their small size (first instars are about 0.2–0.3mm; adult females usually are from 0.5 to10mm long) and their concealment using waxy secretions; beside many species live in hidden habitats (under leaf sheaths, in bark crevices or on roots) so that they can easily escape visual quarantine inspections. Once in a new territory, parthenogenesis and high fecundity favour quick colonization starting from a few females: for example, a single female *Neopulvinaria innumerabilis* may lay up to 8000 eggs (Canard 1968).

9.3.2 Taxonomy of the scale species alien *to* Europe

According to Ben-Dov et al. (2006) the superfamily Coccoidea comprises 22 families, with more than 7300 described species. In Europe, native representatives of 12 families have so far been recognized. On the basis of the best known western and central European coccoid faunas (France, Italy, Hungary) (Ben-Dov et al. 2006, Foldi 2001, Pellizzari and Russo 2004), the total number of scale insects present in Europe is likely to reach about 400–450 species. Aliens recorded in Europe up until 2007 account for 129 species which include the following eight families: Diaspididae (60 species), Pseudococcidae (37), Coccidae (23), Eriococcidae (3), Margarodidae (2), Asterolecanidae, Ortheziidae, and the alien family Phoenicococcidae, each with one species (Table 9.3.1). Unlike for other taxa, aliens represent an important component of the scale fauna currently present in Europe, i.e. near 30% (Fig. 9.3.1).

The remaining five native families (Aclerdidae, Cerococcidae, Kermesidae, Lecanodiaspididae, Micrococcidae) each have one or two species in Europe: none of them is a pest, with the exception of the family Kermesidae (8 species in Europe), in which *Kermes vermilio* and *Nidularia pulvinata* exhibit outbreaks in urban environments only.

One species, *Dactylopius coccus* Costa, representing the alien family Dactylopiidae, has been included among aliens *to* Europe, even though it is present only in Canary islands, Madeira and Azores, where it was intentionally introduced. These islands belong politically to Europe (Spain, Portugal) but biogeographically they belong to Macaronesia, a biogeographic Atlantic region quite distinct from the European continent and with a unique flora and fauna.

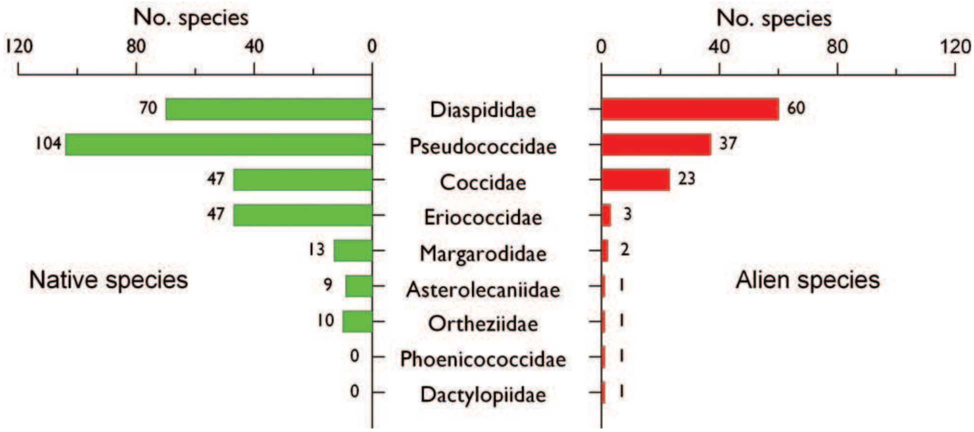

Figure 9.3.1 Taxonomic overview of the scale species alien *to* Europe compared to the native fauna. Species alien *to* Europe include cryptogenics.

Diaspididae

Armoured scale insects are the commonest alien scales incidentally introduced all over the world: this is probably due to their small dimension and camouflage. The 60 alien species account for nearly half (44.6%) of an estimated 130 species in Europe. Many notorious pests of fruit trees such as *Pseudaulacaspis pentagona* (the white peach scale- see factsheet 14.45)) and *Diaspidiotus perniciosus* (San José scale - see factsheet 14.44)) belong to this family: these species are still pests of fruit trees in spite of the introduction of specific parasitoids from their native area. The Asiatic armoured scales of *Citrus* are largely found in European *Citrus* groves and presently number 10 species. Their "invasion" started around 1850 with *Parlatoria ziziphi* and *Lepidosaphes becki* and is still going on with the arrival and establishment of *Unaspis yanonensis* (1969), *Aonidiella citrina* (1994), *Chrysomphalus aonidum* (2000). Several armoured scales commonly occur throughout European greenhouses (e.g. *Diaspis echinocacti*, *Chrysomphalus dictyospermi*, *Diaspis bromeliae*, *Abgrallaspis cyanophylli*), even if they cannot be considered as established. In some cases, species recorded only in greenhouses in northern and central Europe are established outdoors in southern countries (i.e. *Furchadaspis zamiae, Chrysomphalus aonidum*). Some armoured scales thought to be of Afrotropical origin or cryptogenic (e.g. *Aspidiotus nerii*, *Hemiberlesia lataniae, H. rapax*) are very common in natural habitats of the Mediterranean countries (including small islands).

Pseudococcidae

Mealybugs are covered with mealy or cottony wax, have a distinct segmentation and are mobile. The 37 alien mealybugs account for roughly one fourth (25.7%) of the ca. 140 European species and most of them are polyphagous. *Planococcus citri, Pseu-*

dococcus longispinus, P. viburni and *P. calceolariae* arrived and established during the 19th century and are presently the most common species on ornamental plants, both outdoors and indoors. *P. citri*, first recorded in 1813, is still a pest of *Citrus* and ornamental plants. Several mealybugs have been recorded in only one or two countries to date (e.g. *Palmicultor palmarum*, *Phenacoccus madeirensis*, *Rhizoecus americanus, Trochiscococcus speciosus*), both outdoors and in greenhouses, on ornamental plants.

Coccidae

About 70 species of soft scales are recorded in Europe. Of these, there are 23 aliens *to* Europe representing 32.8% of the fauna, and are mainly pests of fruit trees and ornamentals. Among them, the polyphagous *Coccus hesperidum* and *Saissetia oleae*, the well-known Mediterranean Black Scale, are probably the most ancient arrivals which established in the countries surrounding the Mediterranean Basin. Most recent arrivals are *Pulvinaria hydrangeae*, *P. regalis* (see factsheet 14.41), *Ceroplastes japonicus* and, in warmer places, *Protopulvinaria pyriformis*, invasive on trees and ornamental plants in urban environments. Some species, such as *Coccus pseudomagnoliarum*, after first spreading in Mediterranean *Citrus* groves, later became more localised and less common. On the other hand, the American *Pulvinaria innumerabilis* is still considered a pest of vine, more than 40 years after its arrival in European vineyards. Several species (e.g. *Saissetia coffeae*, *S. oleae, C. hesperidum*, *Eucalymnatus tessellatus, Parasaissetia nigra*) are rather common in greenhouses of central and northern Europe, while in southern Europe are outdoors pests.

Eriococcidae

European felt scales number about 50 species. Among them, only three alien felt scales have been so far recorded. The Australian *Eriococcus araucariae* is widespread on *Araucaria* trees growing in Mediterranean countries, the American *E. coccineus* is recorded on succulent plants and *Ovaticoccus agavium* is quite common on *Agave* sp. growing outdoors.

Margarodidae

European margarodids recorded up until now number 15 species. Two alien margarodids, *Icerya purchasi* (the cottony cushion scale) and *I. formicarum,* invaded Europe at very different times. The latter species is known from a single record in 2001 in Corsica and its establishment is unknown. On the other hand, the Australian *I. purchasi* has both established and caused an agricultural and environmental impact. It arrived and established in many Mediterranean countries between the end of 1800 and the first decades of 1900 and was very destructive to *Citrus* groves. The high infestations led to the introduction of the Australian coccinellid *Rodolia cardinalis*, for biological control. Presently, the cottony cushion scale is mainly a pest of ornamental plants such as *Pittosporum, Acacia* and *Mimosa*. It is also a very common species in semi-natural habitats (i.e. the Mediterranean maquis), far away from cultivated areas, where it develops on autochthonous wild plants such as *Cistus*, *Genista*, *Smilax* and *Rosmarinus*. Two other margarodids, *Marchalina hellenica* and *Matsucoccus feytaudi*, are alien *in* Europe, entirely due to deliberate introduction.

Asterolecanidae

About 10 species of asterolecanids are present in Europe. Of these, the only alien pit scale is the Asiatic *Bambusaspis bambusae*, a species associated with bamboos.

Ortheziidae

Ortheziids consist of 10 species in Europe. Among these, *Insignorthezia insignis*, a polyphagous Neotropical species, has been reported in European greenhouses since the end of 19th century. Apparently *I. insignis* is established outdoors only in Portugal and France.

Phoenicococcidae

Phoenicococcus marlatti, the Red Date Palm Scale, thought to originate in the Middle East or North Africa, is the only species currently placed in the family Phoenicococcidae. It is considered a minor pest of commercial dates, whereas in Spain, France and Italy, it infests ornamental palms (mainly *Phoenix canariensis*).

9.3.3 Temporal trends of introduction in Europe of alien scale species

Fig. 9.3.2. presents the temporal variation in the mean number of new alien species recorded per year since 1492. Serious studies of the Coccoidea began in mid 19th century. From that time, to the mid-1970s, the introduction of alien species was relatively constant, averaging 0.66 species per year. Since then, there is an apparent increase in alien introductions, up to an average of 1.15 species per year.

In interpreting this chart, account should be taken of "old" alien species, found and described in Europe, (i.e. *Aspidiotus nerii, Planococcus citri, Coccus hesperidum, Saissetia oleae*) for which the introduction date is based only on the date of their first description. In the case of the most harmful alien scales, the date of first introduc-

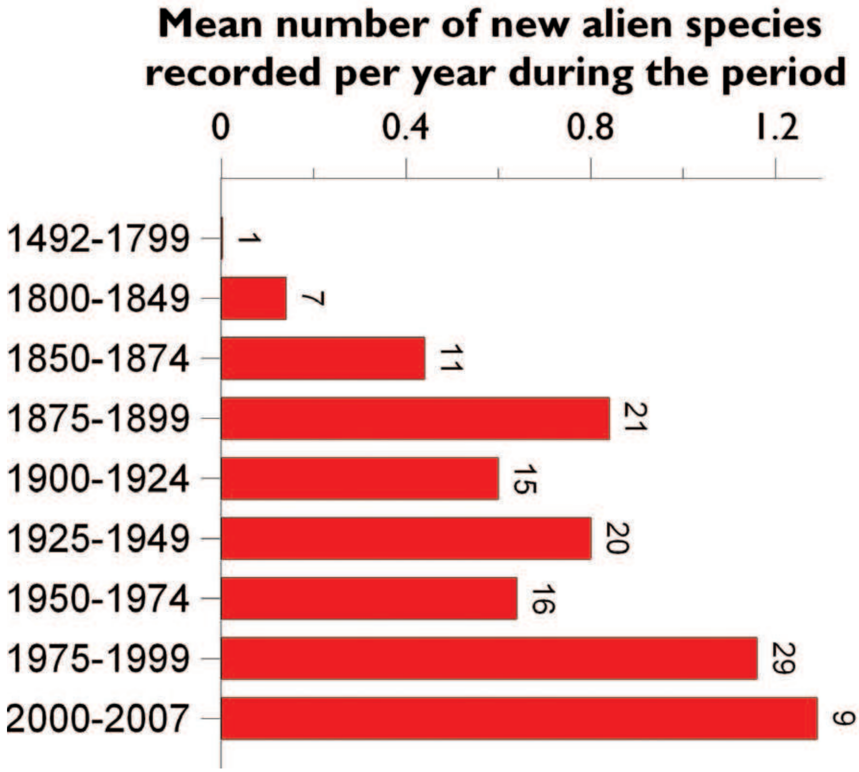

Figure 9.3.2 Temporal trends in the mean number of new records per year of scale species alien *to* Europe from 1492 to 2007. The number above the bar indicates the absolute number of species in this time period.

tion to Europe and the chronology of their invasion is known more precisely (i.e. for *Pseudaulacaspis pentagona*, *Icerya purchasi, Diaspidiotus perniciosus*). Moreover, records of alien scales depend on the presence of specialists in a given country. For instance, during the 1970–80s, advances in systematic knowledge and the increasing number of active coccidologists led to the "discovery" of several species which have probably been introduced a long time before. The great rise in the global exchanges of plants and quarantine inspections can explain the increases in subsequent years up until the present.

Among the scale insects introduced to Europe from the end of 19th century to 1960s there are several pests of fruit trees and *Citrus* (i.e. *Diaspidiotus perniciosus, Lepidosaphes gloverii, Pseudaulacaspis pentagona, Ceroplastes sinensis, Icerya purchasi*), whereas in the last 40 years the most numerous introduced scales are pest of ornamental plants, both outdoors and indoors (i.e. *Pulvinaria regalis, P. hydrangeae, Ceroplastes japonicus, Protopulvinaria pyriformis, Parassaisetia nigra, Trochiscococcus speciosus*), the main scale of agricultural importance being *Neopulvinaria innumerabilis*, a pest of vine.

9.3.4 Biogeographic patterns of the scale species alien to Europe

9.3.4.1 Origin of the alien species

The geographical origin of introduced scale insects shows a large dominance of species from tropical areas, essentially Asia, followed by southern American species (Fig. 9.3.3). The precise origin remains unknown for about one fourth of alien scales. Among the most widespread aliens to Europe are *Diaspidiotus perniciosus* of temperate Asian, *Planococcus citri* from tropical Asia, *Ceroplastes sinensis* from Central-America, *Parthenolecanium fletcheri* from Northern-America, *Saissetia oleae* from the Afrotropics, *Icerya purchasi* from Australasia, and *Lepidosaphes beckii* as cryptogenic species.

9.3.4.2 Distribution of the alien species in Europe

It should be borne in mind that, as for the other arthropod groups, the number of records of alien scales in European countries, reflects, in part, differences of study intensity and the number of local taxonomists. Moreover, the geographic position of some countries such as France, Italy and Spain, whose climatic conditions vary from high montane, continental to Mediterranean, allows establishment of species from very different geographical areas. Two countries present a particularly high number of alien species: France with 90 species and Italy with 92 species (Fig. 9.3.4). Lagging far behind are Spain, Great Britain and Portugal with 50, 43 and 41 species, respectively. The islands of the Atlantic, not represented in the figure, have respectively 51 aliens in the Canaries, 44 in Madeira and 22 in the Azores. There are 12 alien species recorded in at least 20 countries, namely *Coccus hesperidum* (28 countries), *Pulvinaria floccifera* (21), *Saissetia coffeae* (24), *S. oleae* (26), *Aspidiotus nerii* (26), *Diaspidiotus perniciosus* (26), *Pinnaspis aspidistrae* (20), *Pseudaulacaspis pentagona* (21), *Planococcus citri* (22), *Pseudococcus longispinus* (22) and *P. viburni* (26). These are all polyphagous species, with the exception of *Unaspis euonymi,* monophagous on *Euonymus* spp., recorded in 22 countries. A total of 20 species (15%) are present only in one country.

9.3.4.3 Scale species alien in Europe

With regard to scale insects alien *in* Europe, that is originating from another European area where native and introduced through human activity, only very few certain cases are known. *Marchalina hellenica* is native to Turkey and Greece and presently invasive in the small island of Ischia (Italy). It was introduced there in 1960 to study endosymbiosis, but unfortunately escaped from laboratory breeding and presently is a pest of pines (Tranfaglia and Tremblay 1984). *Matsucoccus*

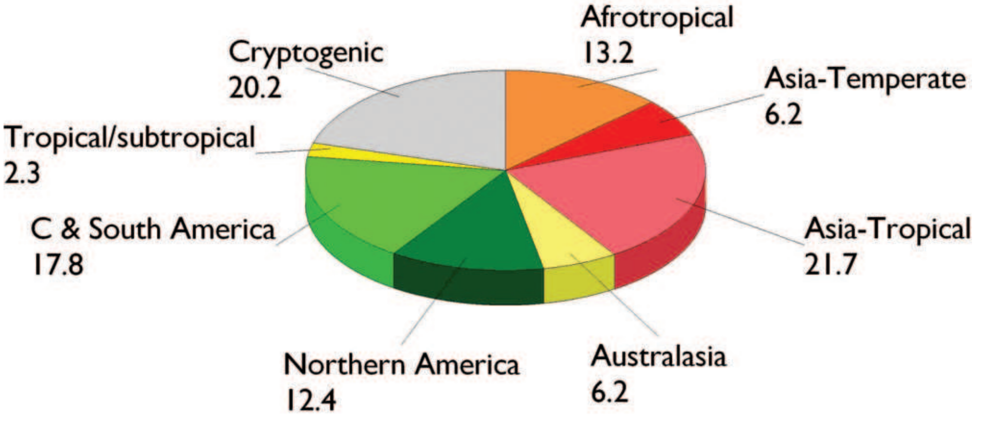

Figure 9.3.3 Geographic origin of the scale species alien *to* Europe.

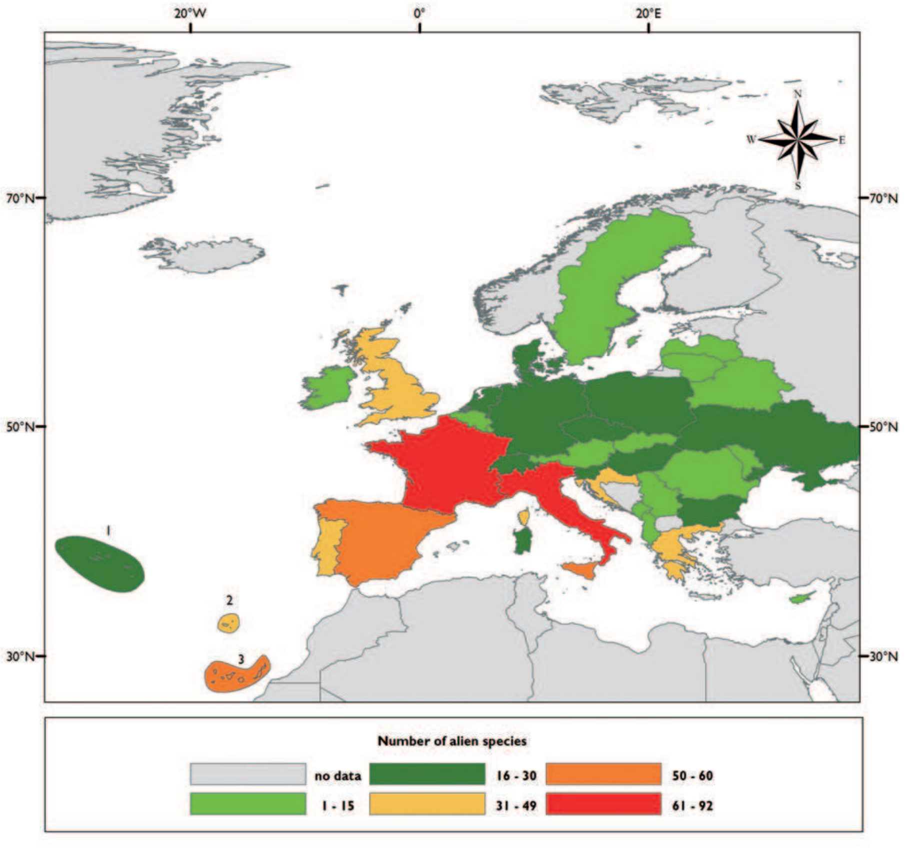

Figure 9.3.4 Numbers of established alien scale species in the European countries and main islands according to Table 9.3.1. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

Figure 9.3.5 *Ceroplastes ceriferus* (Coccidae). Credit: Giuseppina Pellizzari

Figure 9.3.6 *Coccus hesperidum* (Coccidae). Credit: Giuseppina Pellizzari

feytaudi lives on *Pinus pinaster* and is native to the Atlantic regions of France, Spain and Portugal. It was introduced with its host plant in South-eastern France and from there spread towards Italy (Arzone and Vidano 1981). Both *Aonidiella lauretorum* and *A. tinerfensis* are endemic to the Atlantic islands of Canary (Spain) and Madeira (Portugal). They were introduced incidentally with their host plants

Figure 9.3.7 *Parasaissetia nigra* (Coccidae). Credit: Giuseppina.

Figure 9.3.8 *Protopulvinaria pyriformis* (Coccidae). Credit: Giuseppina Pellizzari.

in the Botanic gardens of Sintra and Lisbon (Portugal), where they still persist (Balachowsky 1948).

9.3.6 Pathways of introduction in Europe of alien scale species

Scale insects are highly specialized, sedentary, plant-parasitic insects and the only pathway of introduction is the horticultural and ornamental trade: importation and trade

Figure 9.3.9 *Pulvinaria hydrangeae* (Coccidae). Credit: Nico Schneider

Figure 9.3.10 *Pulvinaria floccifera* (Coccidae). Credit: Nico Schneider

of fruit and *Citrus* trees, ornamental trees and bushes, bulbs and corms, has led to incidental introduction and subsequent spread of scale insects. More recently, the "fashion" of succulent plant cultivation and the subsequent increase in plant importation and plant exchanges among collectors is responsible for the introduction and spread of several species such as *Delottococcus euphorbiae*, *Hypogeococcus pungens, Trochiscococcus speciosus, Vryburgia rimariae, Spilococcus mamillariae* and *Eriococcus coccineus.* Importation of bonsais from Asia could allow the introduction and spread of *Rhizoecus hibisci*, a mealybug living on roots and recently intercepted several times by European quarantine services.

Figure 9.3.11 *Chrysomphalus aonidum* (Diaspididae). Credit: Giuseppina Pellizzari.

Figure 9.3.12 *Unaspis yanonensis* (Diaspididae). Credit: Giuseppina Pellizzari.

9.3.7 Ecosystems and habitats invaded in Europe by alien scale species

Alien, established scale insects colonize strongly anthropogenic habitats such as cultivated agricultural lands, horticultural and domestic habitats, urban environments, gardens and parks, botanic gardens, nurseries and greenhouses, but they have also spread to natural habitats. Mediterranean *Citrus* groves host a large community of alien scales: 18 different species have been so far recorded. These are: *Icerya purchasi Planococcus citri, Pseudococcus calceolariae, P. longispinus, Ceroplastes sinensis, Coccus hesperidum, C. pseudomagnoliarum, Saissetia oleae, Aonidiella aurantii, A. citrina, As-*

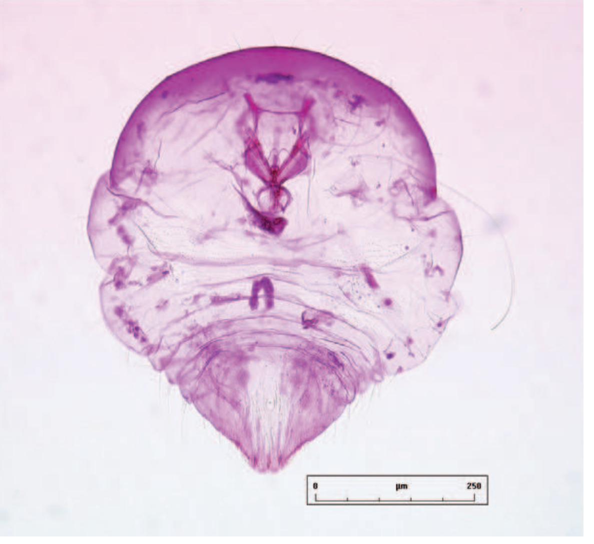

Figure 9.3.13 *Comstockiella sabalis* (Diaspididae). Credit: Jean Francois Germain

Figure 9.3.14 *Ovaticoccus agavium* (Eriococcidae). Credit: Giuseppina Pellizzari

pidiotus nerii, *Chrysomphalus dictyospermi, C. aonidum, Lepidosaphes beckii, L. gloverii, Parlatoria pergandii, P. ziziphi* and *Unaspis yanonensis.* Some polyphagous scales are urban pests, largely distributed in urban parks and gardens, on trees and ornamentals (i.e. *Pulvinaria regalis*, *P. hydrangeae*, *Ceroplastes japonicus*), whereas they are absent or very rare in the countryside. A few monophagous species are only known in Botanical gardens, where they persist outdoors, at a low population levels, on exotic plants

Figure 9.3.15 *Pseudococcus comstocki* (Pseudococcidae). Credit: Giuseppina Pellizzari

Figure 9.3.16 *Pseudococcus longispinus* (Pseudococcidae). Credit: Giuseppina Pellizzari

introduced over there a long before (i.e. *Aonidiella tinerfensis, Pseudaonidia paeoniae* or *Bambusaspis bambusae*).

Several other monophagous species remain strictly associated to their original, exotic ornamental plants, and have a correspondingly wide distribution in Europe (i.e. *Parthenolecanium fletcheri, Pulvinaria mesembryanthemi, Eriococcus araucariae*). On the other hand, some polyphagous species (i.e. *Diaspidiotus perniciosus*, *Pseudaulacaspis pentagona, Pulvinaria floccifera*) have spread from cultivated areas to natural woodland and forest habitats (Balachowsky 1932b, Balachowsky 1936). Others (*Antonina graminis*,

Figure 9.3.17 *Pseudococcus calceolariae* (Pseudococcidae). Credit: Jean Francois Germain

Chorizococcus rostellum and *Trionymus angustifrons*) can be found in grasslands. In natural habitats of Mediterranean countries (including small islands), species such as the armoured scales *Aspidiotus nerii* (see factsheet 14.43), *Hemiberlesia lataniae, H. rapax*, the mealybug *Planococcus citri,* the wax scale *Ceroplastes sinensis* and the Australian *I. purchasi* are quite common on wild autochthonous plants, growing far away from cultivated plants. Their transfer from cultivated plants to authochtonous ones in natural environments confirms that they have fully acclimatized.

9.3.8 Impact of alien scale species

Scale insects are plant pests, especially of fruit trees, woody ornamentals, forest trees and greenhouse plants. They cause damage to plants by sap sucking. Moreover, except for Diaspididae and Asterolecaniidae, they excrete honeydew that covers leaves and fruits and allows the development of sooty mould. This black sooty mould can reduce photosynthesis by 70%, leading to early senescence, with smaller and premature fruits, and loss of aesthetic value (Mibey 1997). Moreover, Coccidae and Pseudococcidae are vectors of closteroviruses. For example, *Planococcus citri* and *Pulvinaria innumerabilis* may transmit the Grapevine Leafroller-associated Virus (GLRaV-1, GLRaV-3) and the Corky Bark disease (GVA, GVB) (Sforza et al. 2003, Zorloni et al. 2006). Diaspididae cause discolouration on leaves, red or black spots on fruits, and twig dieback. Pesticides are commonly applied to control scale insects in fruit orchards and *Citrus* groves. Infestations of alien scales in orchards have led to the introduction to Europe, from their native area, of many natural enemies for biological control purposes.

References

Anagnou–Veroniki M, Papaioannou–Souliotis P, Karanastasi E, Giannopolitis CN (2008) New records of plant pests and weeds in Greece, 1990–2007. *Hellenic Plant Protection Journal* 1: 55–78.

Arzone A, Vidano C (1981) *Matsucoccus feytaudi* Duc. (Homoptera, Margarodidae) fitomizo letale su *Pinus pinaster* in Italia. *Informatore Fitopatologico* 10: 3–10.

Baeta Neves CM (1954) A entomafauna "exoticas" em Portugal. *Portugaliae Acta Biologica* 4: 191–196.

Balachowsky AS (1930) Contribution à l'étude des Coccides de France (3ème note). Coccides nouveaux ou peu connus de la faune de France. *Bulletin de la Société entomologique de France* 178–184.

Balachowsky AS (1932a) *Etude biologique des coccides du basin occidental de la Méditerranée- Encyclopédie Entomologique* XV. Paris : P. Lechevalier & Fils. 214pp.

Balachowsky AS (1932b) La théorie des "places vides" et le peuplement des végétaux par les Coccides *Bulletin de la Société entomologique de France.* Livre du Centenaire:517–522.

Balachowsky AS (1936) La cochenille floconneuse est-elle indigène dans les forêts de France ? *Revue Pathologie Végétale et Entomologie Agricole de France* 23: 307–31.

Balachowsky AS (1938) Les cochenilles de Madère (seconde partie) II Lecaniinae, Eriococcidae, Dactylopinae, Ortheziinae, Margarodidae. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 4: 255–272.

Balachowsky AS (1948) Les cochenilles de France d'Europe, du Nord de l'Afrique, et du bassin Méditerranéen IV - Monographie des Coccoidea; Diaspidinae-IV, Odonaspidini-Parlatorini. *Actualités Scientifiques et Industrielles* 1054: 243–394.

Balachowsky AS (1953) Les cochenilles de France d'Europe, du Nord de l'Afrique, et du bassin Méditerranéen VII - Monographie des Coccoidea; Diaspidinae-IV, Odonaspidini-Parlatorini. *Actualités Scientifiques et Industrielles* 1202: 725–929.

Balachowsky AS (1954) *Les cochenilles Paléarctiques de la tribu des Diaspidini*. Paris : Mémoires Scientifiques de l'Institut Pasteur. 450 pp.

Barbagallo S (1974) Notizie sulla presenza in Sicilia di una nuova cocciniglia degli agrumi *Coccus pseudomagnoliarum* (Kuwana) (Homoptera, Coccidae) osservazioni biologiche preliminari. *Entomologica Bari* 10: 121–139.

Bénassy C (1969) The biological control against coccids of citrus in the country of the French zone. In: Chapman HD (Ed) *Proceedings of the First International Citrus Symposium Vol 2*. Riverside, CA: University of California, 793–799.

Ben-Dov Y (1994) *A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance.* Andover, England: Intercept Publications Ltd. 686 pp.

Ben-Dov Y, Miller DR, Gibson GAP (2006) ScaleNet: a database of the scale insects of the world. http://www.selbarc.usda.gov/scalenet/scalenet.htm.

Berlese A, Leonardi G (1896) Diagnosi di cocciniglie nuove (Cont.). *Rivista di Patologia Vegetale Firenze* 4: 345–352.

Berlese A, Leonardi G (1899) Cocciniglie che minacciano la Frutticultura Europea: 4 Storia della scoperta e diffusione. *Rivista di Patologia Vegetale Firenze* 7: 253–273.

Blanchard R (1883) Les Coccides utiles. *Bulletin de la Société Zoologique de France* 8: 217–328.

Bouché PF (1851) Neue Arten der Schildlausfamilie. *Entomologische Zeitung, Stettin* 12: 110–112.

Canard M (1968) Un nouveau *Pulvinaria* (Hom Coccoidea) nuisible aux arbres d'alignement dans la région Parisienne. *Annales de la Société Entomologique de France (NS)* 4: 951–958.

Chapin E, Germain JF (2005) Des ravageurs des palmiers en France, espèces établies, introduites ou interceptées. In: *Proceedings du 2éme CIAC et de la 7éme CIRA* (N° ISBN: 21–905550–02–3, AFPP Octobre 2005), 9 pp.

Costa OG (1829) (1835) *Fauna del regno di napoli, famiglia de coccinigliferi, o de gallinsetti*. Napoli: Emmiteri. 23 pp.

Del Guercio G (1900) Osservazioni intorno ad una nuova cocciniglia nociva agli agrumi in Italia ed al modo di immunizzare la parte legnosa delle,piante contro la puntura delle coccinglie in generale e di distruggerle. *Nuove Relazione della R. Stazione di Entomologia Agraria Firenze* 3: 3–26.

Douglas JW (1887) Note on some British Coccidae (N°6). *Entomologist's Monthly Magazine* 23: 239–243.

Douglas JW (1888) Notes on some British and exotic Coccidae (N°12). *Entomologist's Monthly Magazine* 25: 150–153.

Douglas JW (1889) The spreading of *Orthezia insignis* in England. *Entomologist's Monthly Magazine* 25: 270.

Fernandes IM 1992 (1990) Contribuiçaos para o conhecimento de Coccoidea (Homoptera) de Portugal I Lista anotada de cochenilhas do jardin do Centro de Zoologia Garcia de Orta. *Serie de zoologia, Lisboa* 17: 53–63.

Foldi I (2001) Liste des cochenilles de France (Hemiptera, Coccoidea). *Bulletin de la société entomologique de France* 103: 303–308.

Germain JF, Matile-Ferrero D, Picart JL, Delvare G, Piron M (2002) Inventory of scale insects in tropical green houses in France and knowledge of their parasitic Hymenoptera, previous to development of biological control. In: Sixième Conférence Internationale sur les Ravageurs en Agriculture Tome 1 AGRO, Montpellier, 253–260.

Germain JF, Matile-Ferrero D (2006) *Comstockiella sabalis* (Comstock), *Crisicoccus pini Kuwana* and *Phenacoccus defectus* Ferris, scales new to France (Hem, Diaspididae and Pseudococcidae). Bulletin de la Société Entomologique de France 111: 395–401.

Gómez-Menor Ortega J (1946) Adiciones a los "Cóccidos de Espana" (la nota). *Eos* 22: 59–106.

Gómez-Menor Ortega J (1957) Adiciones a los cóccidos de Espana (4a nota). *Eos* 33: 39–86.

Goux L (1937) Notes sur les coccides (Hem) de la France (18ème note) Six espèces nouvelles pour la France et remarques sur le genre *Lecanopsis*, *Exaeretopus* et *Luzulaspis. Bulletin de la Société entomologique de France* 42: 93–96.

Green EE (1915) Observations on British Coccidae in 1914, with descriptions of new species. *Entomologist's Monthly Magazine* 51: 175–185.

Green EE (1917) Observations on British Coccidae: with descriptions of new species. *Entomologist's Monthly Magazine* 53: 201–210, 260–269.

Green EE (1920) Observations on British Coccidae No V. *Entomologist's Monthly Magazine* 56: 114–130.

Green EE (1921a) Observations on British Coccidae with descriptions of new species No VI. *Entomologist's Monthly Magazine* 57: 146–152, 189–200.

Green EE (1921b) Observations on British Coccidae: with descriptions of new species-VII. *Entomologist's Monthly Magazine* 57: 257–259.

Green EE (1923) Observations on the Coccidae of the Madeira island. *Bulletin of Entomological Research* 14: 87–99.

Green EE (1928) Observations on British Coccidae - XI With descriptions of new species. *Entomologist's Monthly Magazine* 64: 20–31.

Hodgson CJ (1994) *The scale insect family Coccidae: an identification manual to genera*. Wallingford, Oxon, UK: CAB International. 639 pp.

Jactel H, Meinassieu P, Burban C (1996) Découverte en Corse de *Matsucoccus feytaudi* Duc (Homoptera: Margarodidae), cochenille du pin maritime. *Annales des Sciences Forestières* 53: 145–152.

Jansen MGM (1995) Scale insects (Homoptera: Coccinea) from import interceptions and greenhouses in the Netherlands. *Israel Journal of Entomology* 29: 131–146.

Kawecki Z (1935) Czerwce (Coccidae) województwa krakowskiego I kieleckiego zebrane w latach 1933–1934 (Die schildläuse (Coccidae) der wojewodschaften Kraków und kielce die in den jahren 1933–1934 gesammelt wurden) Sprawozdanie Komisji Fizjograficznej Polskiej Akad Umiejetnosci . *Annual Report of the Physiographical Commission of Polish Academy of Sciences & Letters* 68: 73–90.

Koteja J, Zak-Ogaza B (1966) Investigations on scale insects (Homoptera, Coccoidea) of the Pieniny Klippen Belt. *Acta Zoologica Cracoviensia* 11: 305–332.

Kozár F, Tzalev M, Viktorin RA, Horváth J (1979) New data to the knowledge of the scale insects of Bulgaria (Homoptera: Coccoidea). *Folia Entomologica Hungarica* 32: 129–132.

Kozarzhevskaya E, Reitzel J (1975) The scale insects (Homoptera: Coccoidea) of Denmark. *Statens Forsogsvirksomhed I Plantkultur Beretning Copenhagen* 1226: 1–40.

Leonardi G (1897) Monografia de genere *Aspidiotus* (nota preventiva). *Rivista di patologia Vegetale Firenze* 5: 283–286.

Leonardi G (1898) Generi e specie di diaspi Saggio di sistematica degli *Aspidiotus*. *Rivista di patologia Vegetale Firenze* 6: 48–78.

Leonardi G (1899) Sopra una Cocciniglia che danneggia la *Araucaria excelsa*. *Bollettino di Entomologia Agraria e Patologia Vegetale* 6: 53–55.

Leonardi G (1903) (1904) Generi e specie di dispini Saggio di sistematica delle parlatoriae. *Annali della Regia Scuolo di Agricoltura di Portici* 5: 1–59.

Leonardi G (1906) (1905) Diagnosi di cocciniglie nuove. *Redia* 3: 1–7.

Leonardi G (1913) Nuove specie di cocciniglie raccolte in Italia. *Bollettino del Laboratorio di Zoologia Generale e e Agraria della Regia Scuola Superiore Agricoltura di Portici* 7: 59–65.

Leonardi G (1918) Terza contribuzione alla conoscenza delle cocciniglie Italiane. *Bollettino del R Laboratorio di Entomologia Agraria di portici* 12: 188–216.

Leonardi G (1920) *Monografia delle cocciniglie Italiane*. Portici: Della Torre 555 pp.

Lindinger L (1908) (1907) Ein neuer Orchideen-schädling, *Leucodiaspis cockerelli* (de Charm). *Green Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten Hamburg* 3: 121–124.

Longo S, Mazzeo G, Russo A, Siscaro G (1994) *Aonidiella citrina* (Coquillet) nuovo parassita degli agrumi in Italia. *Informatore Fitopatologico*, 12, 19–23.

Lucas H (1853) *Coccus ziziphi*. *Annales de la Société Entomologique de France* 1: 28–29.

Lupo V (1938) Revisione delle cocciniglie italiane II *Howardia*, *Adiscodiaspis*, *Chionaspis*, *Pinnaspis*, *Fiorinia*, *Kuwanaspis. Bollettino del Laboratorio di zoologia generale ed agraria di Portici* 29: 255–322.

Lupo V (1948) Revisione delle cocciniglie Italiane. V. (*Pseudoparlatoria, Parlatoria*). Bollettino del R. Laboratorio di Entomologia Agraria. Portici 8: 33–79.

Malumphy CP (2005) *Eulecanium excrescens* (Ferris) (Hemiptera: Coccidae), an Asian pest of woody ornamentals and fruit trees, new to Britain. *British Journal of Entomology and Natural History* 18: 45–49.

Marchal P (1907) La cochenille floconneuse. *Bulletin de la Société Naturelle d'Acclimatation* 186–199.

Marotta S (1987) I Coccidi (Homoptera: Coccoidea: Coccidae) segnalati in Italia, con riferimenti bibliografici sulla tassonomia, geonomia, biologia e piante ospiti. *Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'* 44: 97–119.

Marotta S (1992) Ricerche su pseudococcidi (Homoptera: Coccoidea) dell'Italia centro-meridiionale. *Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'* 47: 63–111.

Marotta S (1995) Due *Rhizoecus* Kunckel d'Herculais, 1878 (Homoptera Coccoidea Pseudococcidae) nuovi per la fauna italiana. Bollettino di Zoologia Agrari e di Bachicoltura (Milano) Ser II 27: 117–121.

Marotta S, Garonna AP (1991) Homoptera Coccoidea nuovi e poco conosciuti delle piante grasse in Italia. Atti Congn nza It Ent, Bari-martina (TA), 23–28: 741–746.

Marotta S, Tranfaglia A (1990) New and little known species of Italian scale insects (Homoptera: Coccoidae). In: *Proceedings of the 6th International Symposium of Scale Insect Studies, part II. Kraków, Poland, August 1990.* Kraków: Agricultural University Press, 107–112.

Mazzeo G, Russo A, Suma P (1999) Phenacoccus solani Ferris (Homoptera Coccoidea) on ornamental in Italy. Bollettino di Zoologia Agraria e di Bachicoltura *(Milano)* 31: 31–35.

Melis A (1943) Contributo alla conoscenza dell'*Aspidiotus pernicious*. *Redia* 29: 1–170.

Menozzi C (1933) Contributo alla conoscenza delle cocciniglie (Hemip Coccidae) d'Italia (prima nota). *Bollettino della Società Entomologica Italiana Firenze* 65: 41–47.

Mibey RK (1997) Sooty Moulds. In: Ben-Dov Y, Hodgson CJ (Eds) *World Crop Pests Soft Scale Insects, Their Biology, Natural Enemies and Control,* vol. 7A. Amsterdam: Elsevier, 275–288.

Mori N, Pellizzari G, Tosi L (2001) *Ceroplastes ceriferus* (Fabricius) (Hemiptera; Coccoidea): new pest of ornamentals in Europe? *Bollettino di Zoologia Agraria e di Bachicoltura (Milano)* 33: 331–336.

Morrison H (1939) Taxonomy of some scale insects of the genus *Parlatoria* encountered in plant quarantine inspection work. *United States Department of Agriculture, Miscellaneous Publications* 344: 1–34.

Newstead R (1898) Observations on Coccidae (N°7). *Entomologist's Monthly Magazine* 34: 92–99.

Olivier GA (1791) Cochenille. *Coccus.* Genre d'insectes de la première section de l'ordre des Hémiptères. In: Olivier GA (Ed.), Encyclopédie méthodique, Paris, 85–100.

Pegazzano F (1949) Un diaspino nuovo per la fauna Paleartica: *Pseudaonidia poeoniae* Cockll (Hemiptera, Coccidae). *Redia* 34: 233–235.

Pellizzari G (1993) Homoptera Coccoidea nuovi o poco noti per la fauna italiana. *Bollettino di Zoologia Agraria e di Bachicoltura* 25 (1): 49–55.

Pellizzari G, Camporese P (1994) The *Ceroplastes* species (Homoptera: Coccoidea) of the Mediterranean basin with emphasis on *C japonicus* Green. *Annales de la Societe entomologique de France (NS)* 30: 175–192.

Pellizzari G, Russo, A (2004) List of the scale insects (Hemiptera, Coccoidea) of Italy. In Proceedings of the 10th International Symposium on Scale Insects Studies, Adana, April 2004, 167–183.

Porcelli E (1990) Cocciniglie nuove per l'Italia. *Frustula entomologica NS* 26: 31–38.

Risso A (1813) mémoire sur l'histoire naturelle des oranges, bigaradiers, limettiers, cédratiers, limoniers ou citronniers, cultivés dans le département des Alpes-Maritimes. *Annales du Muséum National d'Histoire naturelle Paris* 20: 169–212, 401–431.

Ruiz Castro A (1944) Un Coccido ampelofago nuevo en espana (*Aspidiotus uvae* Comstock). Boletín *de* Patologia *Vegétal* y *Entomologia Agricola* 13: 55–73.

Russell L (1941) A classification of the scale genus *Asterolecanium*. *United States Department of agriculture, Miscellaneous Publications* 424: 1–319.

Russo A, Mazzeo G (1992) *Rhizoecus americanus* (Hambleton) e *Pseudaulacaspis cockerelli* (Cooley) (Homptera Coccoidea) dannosi alle painte ornamentali in Italia. *Bollettino di Zoologia agraria e di bachicoltura Ser II* 24: 215–221.

Russo A, Mazzeo G (1996) *Dactylopius coccus* Costa (Homoptera, Coccoidea): la cocciniglia del carminio. *Informatore Fitopatologico* 4: 10–13.

Russo A, Mazzeo G, Suma P (1999) Sulla presenza di *Entaspidiotus lounsburyi* (Marlatt, 1908) su Mesembryanthemaceae in Italia (Homoptera, Coccoidea). *Redia* 82: 83–87.

Seabra AF de (1942) Contribuiçoes para o inventario da fauna Lusitânica Insecta: Homoptera (Coccidae). *Aditamento Memorias y Estudos do Museo Zoologico da Universidade de Coimbra* 128: 1–2.

Sforza R, Boudon-Padieu E, Greif C (2003) New mealybug species vectoring Grapevine leafroll-associated viruses-1 and-3 (GLRaV-1 and –3). *European Journal of Plant Pathology* 109: 975–981.

Signoret V (1869a) Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 4ème partie. *Annales de la Société Entomologique de France* 9: 109–138.

Signoret V (1869b) Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 5ème partie. *Annales de la Société Entomologique de France* 9: 431–452.

Signoret V (1875) Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 15e partie. *Annales de la Société Entomologique de France* (série 5) 5: 305–352.

Süss L, Trematerra P (1986) *Hypogeococcus festerianus* (Lizer y Trelles), nocivo alle Cactacee ormamentali in Liguria. *Informatore Fitopatologico* 10: 43–46.

Targioni Tozzetti A (1884) Relazione intorno ai lavori della R Stazione di Entomologia Agraria di Firenze per gli anni 1879–80 article V-omotteri. *Annali di Agricoltura (Ministero di Agricoltura, Industria e commercio) Firenze, Roma*: 383–414.

Targioni Tozzetti A (1867) Studii sulle Cocciniglie. *Memorie della Società Italiana di Scineze Naturali Milano* 3: 1–87.

Targioni Tozzetti A (1886) (1885) Sull'insetto che danneggia I gelsi. *Rivista di bachicoltura* 18: 1–3

Tranfaglia A (1976) Studi sugli Homoptera Coccoidea IV Su alcune Cocciniglie nuovo o poco conosciute per l'Italia (Coccidae, Eriococcidae, Pseudococcidae). *Bollettino del laboratorio di entomologia Agraria 'Filippo Silvestri' Portici* 33: 128–143.

Tranfaglia A (1981) Studi sugli Homoptera Coccoidea V Notizie morfo-sistematiche su alcune specie di Cocciniglie con descrizione di tre nuove specie di Pseudococcidi. *Bollettini del Laboratorio di Entomologia Agraria 'Filippo Sivestri' Portici* 38: 3–28.

Tranfaglia A, Tremblay E (1984) Faunistic and systematic studies on Italian scale insects. In *Verhandlungen des Zehnten Internationalen Symposiums über Entomofaunistik Mitteleuropas (*SIEEC X), August 1983, Budapest (1984), 372–374.

Tranfaglia A, Viggiani G (1988) Cocciniglie di importanza economica in Italia e loro controllo. Benevento, Regione Campania, Italy: Assessorato Agricoltura, Servizio Sperimentazione Abete Grafica 30pp.

Williams DJ (1985) Scale insects (Homoptera: Coccoidea) of Tresco, isles of Sicily. *Entomologist's Gazette* 36: 135–144.

Williams DJ, Pellizzari G (1997) Two species of mealybugs (Homoptera Pseudococcidae) on the roots of Aloaceae in greenhouses in England and Italy. *Bollettino di Zoologia agraria e di Bachicoltura ser II* 29: 157–166.

Zahradnik J (1990) Die Schildläuse (Coccinea) auf Gewächshaus- un Zimmerpflanzen in den Tschechischen Ländern. *Acta Universitatis Carolinae Biologica* 34: 1–160.

Zorloni A, Prati S, Chiesa S, Bianco PA (2006) Transmission of grapevine leafroll associated virus 3 by the soft scale insect *Neopulvinaria innumerabilis* Rathvon. In *Abstracts* of the *13th Congresso Nazionale* della Società Italiana di Patologia Vegetale *September, 2006*, Foggia, 17.

Pellizzari G, Danzig E (2007) The bamboo mealybugs *Balanococcus kwoni* n. sp. and *Palmicultor lumpurensis* (Takahashi) (Hemiptera, Pseudococcidae) Zootaxa 1583: 65–68.

Table 9.3.1. List and main characteristics of the scale species alien to Europe. Status: A: Alien to Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 29/05/200

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Asterolecaniidae								
Bambusaspis bambusae (Boisduval, 1869)	A	Phyto-phagous	Asia-Tropical	1941, IT-SIC	DK, ES, FR, GB, IT, IT-SIC, PT, PT-MAD	I2, J100	*Bambusa*	Russell (1941)
Coccidae								
Ceroplastes ceriferus (Fabricius, 1798)	A	Phyto-phagous	Central-America	1921, IT	IT, ES-CAN, GB	I2	Polyphagous	Green (1921b), Mori et al. (2001)
Ceroplastes floridensis Comstock, 1881	A	Phyto-phagous	South-America	1930, FR	CY, FR, GR, IL, MT, PT-AZO, PT-MAD	I2	Polyphagous	Balachowsky (1930)
Ceroplastes japonicus Green, 1921	A	Phyto-phagous	Asia-Tropical	1930, FR	FR, IT, HR, SI	I2	Polyphagous	Pellizzari and Camporese (1994)
Ceroplastes sinensis Del Guercio 1900	A	Phyto-phagous	Central-America	1890, IT	AL, ES, ES-CAN, FR, FR-COR, GR,HR, IT, IT-SIC, MT, ME, PT, PT-AZO, PT-MAD, RO	I2	Polyphagous	Del Guercio (1900)
Coccus hesperidum Linnaeus, 1758	A	Phyto-phagous	Tropical/subtropical	1829, IT	BE, BG, CH, CY, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SIC, IT-SAR, LV, NL, ME, MT, PT, PT-AZO, PT-MAD, SK, SI, RS, RO, UA	I2	Polyphagous	Costa (1829)
Coccus longulus (Douglas, 1887)	A	Phyto-phagous	Tropical/subtropical	2001, FR	FR, ES-CAN	I2	Polyphagous	Foldi (2001)
Coccus pseudohesperidum (Cockerell, 1895)	A	Phyto-phagous	Southern-America	1920, GB	GB, LV, UA	I2	Polyphagous	Green (1921a)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Coccus pseudomagnoliarum (Kuwana, 1914)	A	Phyto-phagous	Asia-Tropical	1974, GR, IT	FR, GR, HR, IT, IT-SIC,ME, SI	I2	*Citrus*	Barbagallo (1974)
Eucalymnatus tessellatus (Signoret, 1873)	A	Phyto-phagous	Southern-America	1932, FR	BG, DK, DE, ES, ES-CAN, FR, IL, PT-MAD, PL, UA	I2, J100	*Livistona* ., Palms	Balachowsky (1954)
Eulecanium excresens Ferris, 1920	A	Phyto-phagous	Northern-America	1998, GB	GB	I2	*Juglans*, *Wisteria*	Malumphy (2005)
Cryptinglisia lounsburyi (Cockerell, 1900)	A	Phyto-phagous	Afrotropical	1982, IT	IT	I2	*Pelargonium*	Marotta (1987)
Neopulvinaria innumerabilis (Rathvon, 1880)	A	Phyto-phagous	Northern-America	1961, FR	FR, HR, IT, SI	I2	*Vitis*, polyphagous	Hodgson (1994)
Parasaissetia nigra (Nietner, 1861)	A	Phyto-phagous	Afrotropical	1900, IT	AL, ES, ES-CAN,FR, FR-COR, IT, IT-SIC, MT, PT, PT-AZO, PT-MAD, PL, RO	I2	Polyphagous	Marotta (1987)
Parthenolecanium fletcheri (Cockerell, 1893)	A	Phyto-phagous	Northern-America	1935, PL	AT, BG, CH, CZ, DE, FR, HU, HR, LV, NL, PL, RO, S	I2	*Cupressus*, *Thuya*	Kawecki (1935)
Protopulvinaria pyriformis (Cockerell, 1894)	A	Phyto-phagous	Asia-Tropical	1991, IT	AL, ES, ES-CAN, FR, GR, IT, IT-SIC, PT, PT-AZO, PT-MAD	I2	Polyphagous	Marotta and Tranfaglia (1990)
Pulvinaria floccifera (Westwood, 1870)	A	Phyto-phagous	Asia-Temperate	1889, FR	CH, CY, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, NL,PT, PT-MAD, SE, SI, RO, RU	I2	*Ilex aquifolium*, *Taxus baccata*	Marchal (1907)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pulvinaria horii Kuwana, 1902	A	Phyto-phagous	Asia-Temperate/ Japan	2001, FR, GR	FR, GR, HR, IT, IT-SIC,ME, SI	F, G	*Aesculus, Acer, Ficus*	Foldi (2001)
Pulvinaria hydrangeae (Steinweden, 1946)	A	Phyto-phagous	Northern-America	2001, FR	CH, DE, FR, GB, HR, IT, LU, NL, SI	I2	Polyphagous	Foldi (2001)
Pulvinaria psidii Maskell, 1893	A	Phyto-phagous	Tropical/ subtropical	1928, GB	GB, ES-CAN	I2	Polyphagous	Green (1928)
Pulvinaria regalis Canard, 1968	A	Phyto-phagous	Asia-temperate	1968, FR	AT, BE, CH, DE, FR, GB, IRL, LU, NL	I2	Polyphagous	Canard (1968)
Pulvinariella mesembryanthemi (Vallot, 1830)	A	Phyto-phagous	Afrotropical/ South Africa	1829, FR	ES, ES-CAN,FR, GB, GR, IT, IT-SAR, IT-SIC, MT, PT-MAD, SI	I2	Aizoaceae	Balachowsky (1932a)
Saissetia coffeae (Walker, 1852)	A	Phyto-phagous	Afrotropical	1867, IT	BG, CH, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, HU, IT, IT-SAR, IT-SIC, LV, MT, NL, PT, PT-AZO, PT-MAD, PL, RO, S, UA	I2, J100	Polyphagous	Leonardi (1920)
Saissetia oleae (Olivier, 1791)	A	Phyto-phagous	Afrotropical	1791, FR, IT	AL, AT, BG, CH, CY,DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, IT-SAR, IT-SIC, ME, PT, PT-AZO, PT-MAD, NL, RO, SK, SI, RS, UA	I, I2	*Olea europea, Nerium oleander,* polyphagous	Olivier (1791)
Dactylopiidae								
Dactylopius coccus Costa, 1829	A	Phyto-phagous	Central-America	1827, ES-CAN	ES-CAN, PT-AZO, PT-MAD	I	Cactaceae	Russo and Mazzeo (1996)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Diaspididae								
Abgrallaspis cyanophylli (Signoret, 1869)	C	Phyto-phagous	Cryptogenic	1868, FR	BG, CZ, DK, ES-CAN, FR, FR-COR, IT, IT-SAR, IT-SIC, PL	I2	Polyphagous	Signoret (1869a)
Aonidiella aurantii (Maskell, 1879)	A	Phyto-phagous	Asia-Tropical/ China	1881, IT	CY, ES, ES-CAN, FR, FR-COR, GR, IT, IT-SAR, IT-SIC, PT-MAD	I, I2	*Citrus*, Polyphagous	Leonardi (1918)
Aonidiella citrina (Coquillett, 1891)	A	Phyto-phagous	Asia-tropical	1994, IT	CY, FR, FR-COR, IT	I, I2	*Citrus*, Polyphagous	Longo et al. (1994)
Aonidiella taxus Leonardi 1906	A	Phyto-phagous	Asia-tropical	1906, IT	ES, FR, IT, IT-SIC	I2	*Taxus*	Leonardi (1906)
Aonidiella tinerfensis (Lindinger, 1911)	A	Phyto-phagous	Africa/ Canary Islands	1936, PT	PT	I2	*Dracaena*	Fernandes (1992)
Aspidiotus destructor Signoret 1869	C	Phyto-phagous	cryptogenic	1898, IT	FR, IT	J100	Palms, Polyphagous	Leonardi (1898)
Aspidiotus nerii (Bouché, 1833)	A	Phyto-phagous	Afrotropical	1829, IT	AL, CH, CY, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, PL, RO, RS, SE, SI	I, I2	*Nerium oleander*, Polyphagous	Leonardi (1920)
Aulacaspis tubercularis Newstead, 1906	C	Phyto-phagous	Cryptogenic	1990, IT	IT, IT-SIC, PT	I2	*Mangifera*	Porcelli (1990)
Chrysomphalus aonidum (Linnaeus, 1758)	A	Phyto-phagous	Southern-America	1895, IT	BE, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, PT-MAD, PL, RS	I2	*Citrus*, Polyphagous	Leonardi (1920)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Chrysomphalus dictyopsermi (Morgan, 1889)	A	Phyto-phagous	Asia-Tropical	1896, IT	CZ,DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, PT, PL,PT-AZO, PT-MAD, PL, RO, RS	I2, J100	*Citrus*, Polyphagous	Berlese and Leonardi (1896)
Chrysomphalus pinnulifer (Maskell, 1891)	C	Phyto-phagous	Cryptogenic	1957, ES	ES, ES-CAN, PT-MAD	I2	Polyphagous	Gómez-Menor Ortega (1957)
Comstockiella sabalis (Comstock, 1883)	A	Phyto-phagous	Northern-America	2005, FR	FR	I2	Palms	Germain and Matile-Ferrero (2006)
Diaspidiotus osborni (Newell & Cockerell, 1898)	A	Phyto-phagous	Northern-America	1979, BG	BG, CH, IT, IT-SIC	I2	*Platanus*	Kozár et al. (1979)
Diaspidiotus perniciosus (Comstock, 1881)	A	Phyto-phagous	Asia-temperate/ China	1928, HU	AT, BG, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MD, NL, PT, PT-MAD, PL, RO, SE, SI, UA	G, I	Fruit trees, Polyphagous	Melis (1943)
Diaspidiotus uvae (Comstock 1881)	A	Phyto-phagous	Northern-America	1944, ES	ES, ES-CAN	I	Polyphagous	Ruiz Castro (1944)
Diaspis boisduvalii Signoret 1869	A	Phyto-phagous	Southern-America	1868, FR	BG, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, IT, IT-SIC, PT, PT-MAD, SE	I2, J100	Polyphagous	Signoret (1869b)
Diaspis bromeliae (Kerner, 1778)	A	Phyto-phagous	Southern-America	1868, FR	A, B, BG, CH, CZ, DE, DK, ES, ES-CAN FR, GB, HU, IT, IT-SIC, MT, NL, PT-AZO, PT-MAD, PL, SE	I2, J100	Bromeliaceae	Signoret (1869b)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Diaspis echinocacti (Bouché, 1833)	A	Phyto-phagous	Central-America	1827, IT	DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, LU, LT, PT, PT-MAD	I2, J100	Cactaceae	Leonardi (1920)
Entaspidiotus lounsburyi (Marlatt, 1908)	A	Phyto-phagous	Afrotropical/ South Africa	1999, IT, IT-SIC	IT, IT-SIC	I2	Aizoaceae	Russo et al. (1999)
Eulepidosaphes pyriformis (Maskell, 1897)	A	Phyto-phagous	Afrotropical/ South Africa	1985, GB	GB	I2	Polyphagous	Williams (1985)
Fiorinia fioriniae (Targioni Tozzetti, 1867)	A	Phyto-phagous	Asia-Tropical	1867, IT	ES-CAN, FR, GR, IT, IT-SIC, MT, PT-MAD	I2	Polyphagous	Targioni Tozzetti (1886), (1885)
Fiorinia pinicola Maskell, 1897	A	Phyto-phagous	Asia-Tropical	1952, PT	IT, PT	I2	Polyphagous	Baeta Neves (1954)
Furchadaspis zamiae (Morgan, 1890)	A	Phyto-phagous	Afrotropical	1895, IT	CH, CZ, DE, DK, ES, ES-CAN, FR, GB, IT, IT-SAR, IT-SIC, PT, PT-AZO, PT-MAD, PL, SE, UA	I2, J100	Cycadaceae, Zamiaceae	Berlese and Leonardi (1896)
Gymnaspis aechmeae Newstead, 1898	C	Phyto-phagous	Cryptogenic	1898, GB	BE, BG, CH, CZ, DE, ES, FR, IT, IRL, Pl, RO, S	I2, J100	Bromeliaceae	Newstead (1898)
Hemiberlesia lataniae (Signoret, 1869)	C	Phyto-phagous	Cryptogenic	1869, FR	AT, BE, BG, CY, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, GR, IT, IT-SIC, PT, PT-MAD, PL, RO	I2, J100	Polyphagous	Signoret (1869a)
Hemiberlesia palmae (Cockerell, 1892)	A	Phyto-phagous	Southern-America	1920, GB	CY, GB, PT, PT-MAD	I2, J100	Palms	Green (1920)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hemiberlesia rapax (Comstock, 1881)	C	Phyto-phagous	Cryptogenic	1881, IT	CZ, ES, ES-CAN, FR, GR, IT, IT-SAR, IT-SIC, MA, PT, PT-AZO, PT-MAD, PL	I2, J100	Polyphagous	Leonardi (1920)
Howardia biclavis (Comstock, 1883)	C	Phyto-phagous	Cryptogenic	1896, IT	FR, IT	I2, J100	Polyphagous	Berlese and Leonardi (1896)
Ischnaspis longirostris (Signoret, 1882)	C	Phyto-phagous	Cryptogenic	1954, FR	CZ, DK, ES-CAN, F	I2, J100	Polyphagous	Balachowsky (1954)
Kuwanaspis pseudoleucaspis Kuwana, 1923	A	Phyto-phagous	Asia-temperate/ China Japan	1900, IT	AL,FR, HR, IT, PL, SI, UA	I2	Bamboos	Lupo (1938)
Lepidosaphes beckii (Newman, 1869)	C	Phyto-phagous	Cryptogenic	1850, DE	BG, CY, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, IT-SAR, IT-SIC, MA, PT, PT-AZO, PT-MAD	I2	Polyphagous	Bouché (1851)
Lepidosaphes gloverii (Packard, 1869)	C	Phyto-phagous	Cryptogenic	1884, IT	ES, FR, FR-COR, HR, IT, IT-SAR, IT-SIC, GR, P	I2	*Citrus*, Polyphagous	Targioni Tozzetti (1884)
Leucaspis podocarpi (Green, 1929)	A	Phyto-phagous	Australasia/ New-Zealand	1985, GB	GB	I2	Podocarpus	Williams (1985)
Lindingaspis rossi (Maskell, 1891)	A	Phyto-phagous	Australasia/ Australia	1942, PT	ES, FR, IT, IT-SIC, PT, PT-MAD	F, G, I2	Polyphagous	Seabra de (1942)
Lopholeucaspis cockerelli (Grandpré & Charmoy, 1899)	C	Phyto-phagous	Cryptogenic	1908, DE	DE, GB, GR	J100	Orchidaceae	Lindinger (1908)
Oceanaspidiotus spinosus (Comstock, 1883)	C	Phyto-phagous	Cryptogenic	1890, IT-SIC	ES, ES-CAN, GB, IT, IT-SIC, PT, PT-AZO, PT-MAD	I2, J100	Polyphagous	Leonardi (1897)
Odonaspis greenii (Cockerell, 1902)	A	Phyto-phagous	Asia-Tropical	1963, CZ	CZ, ES, IT	I2, J100	Bamboos	Zahradnik (1990)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Odonaspis secreta (Cockerell, 1896)	A	Phyto-phagous	Asia-Tropical	1929, FR	FR	I2	Bamboos	Balachowsky (1930)
Opuntaspis philococcus (Cockerell, 1893)	A	Phyto-phagous	Southern-America	1929, FR	FR	I2	Opuntia	Balachowsky (1932a)
Parlatoria blanchardi Targioni Tozzetti, 1883	A	Phyto-phagous	Arabian peninsula	1947, IT	ES, FR, IT, PT	I2	Palms	Lupo (1948)
Parlatoria camelliae Comstock, 1883	A	Phyto-phagous	Asia-Tropical	1903, IT	ES, FR, IT, IT-SIC, PT, PT-MAD	I2	*Camellia*, Polyphagous	Leonardi (1903)
Parlatoria crotonis Douglas, 1867	C	Phyto-phagous	Cryptogenic	1887, GB	FR, GB, IT, HU	I2	*Croton*	Douglas (1887)
Parlatoria pergandii Comstock 1881	C	Phyto-phagous	Cryptogenic	Last 1899, IT	CY, DE, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-MAD	I2, J100	*Citrus*, Polyphagous	Berlese and Leonardi (1899)
Parlatoria proteus (Curtis, 1843)	C	Phyto-phagous	Cryptogenic	1939, FR	BG, CZ, DE, DK, FR, PL, UA	I2, J100	Palms, orchids, Polyphagous	Morrison (1939)
Parlatoria theae Cockerell, 1896	C	Phyto-phagous	Cryptogenic	1953, FR	ES, FR, PT-MAD, PL, UA	I2	Polyphagous	Balachowsky (1953)
Parlatoria ziziphi (Lucas, 1853)	A	Phyto-phagous	Asia-Tropical	1853, FR	BG, CY, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, PT, UA	I2	*Citrus*, Rutaceae	Lucas (1853)
Pinnaspis aspidistrae (Signoret, 1869)	A	Phyto-phagous	Asia-Tropical	1868, FR	B, BG, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, HU, IT,IT-SIC, IE, MT, NL, PT, PT-MAD, PL, S, UA	J100	Polyphagous	Signoret (1869b)
Pinnaspis buxi (Bouché, 1851)	C	Phyto-phagous	Cryptogenic	1851, DE	DE, DK, FR, IT	J100	Polyphagous	Balachowsky (1938)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pinnaspis strachani (Cooley, 1899)	C	Phyto-phagous	Cryptogenic	1988, IT	DE, ES-CAN, FR, GB, IT, PL	J100	Polyphagous	Tranfaglia and Viggiani (1988)
Poliaspis cycadis Comstock, 1833		Phyto-phagous	Asia-tropical	2007, GR	GR	J100	Cycadaceae, Ericaceae	Anagnou–Veroniki et al. (2008)
Pseudaonidia paeoniae (Cockerell, 1899)	A	Phyto-phagous	Asia-Tropical	1949, IT	IT	J100	*Camellia*	Pegazzano (1949)
Pseudaulacaspis cockerelli (Cooley, 1897)	A	Phyto-phagous	Asia-Tropical	1992, IT	FR, FR-COR, IT, IT-SIC, SI	J100	Polyphagous	Russo and Mazzeo (1992)
Pseudaulacaspis pentagona (Targioni Tozzetti, 1886)	A	Phyto-phagous	Asia-Tropical?	1886, IT	AT, BG, CH, DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MA, NL, PT, PT-MAD, SI, UA	G, J, I	Fruit trees, Polyphagous	Targioni Tozzetti (1867)
Pseudoparlatoria parlatorioides (Comstock, 1883)	C	Phyto-phagous	Cryptogenic	1918, IT	CZ, DE, ES, FR, IT, PT-MAD	I2, J100	Polyphagous	Leonardi (1918)
Pseudoparlatoria ostreata Cockerell, 1892	C	Phyto-phagous	Cryptogenic	1954, FR	FR	I2	Polyphagous	Balachowsky (1954)
Rutherfordia major (Cockerell, 1894)	C	Phyto-phagous	Cryptogenic	2002, FR	FR	I2, J100	Polyphagous	Germain et al. (2002)
Selenaspidus albus McKenzie, 1953	A	Phyto-phagous	Afrotropical/ South Africa	1991, IT	IT	I2	Euphorbiaceae	Marotta and Garonna (1991)
Umbaspis regularis (Newstead, 1911)	A	Phyto-phagous	Afrotropical	1990, IT	IT	I2	Polyphagous	Pellizzari (1993)
Unaspis euonymi (Comstock, 1881)	A	Phyto-phagous	Asia-Temperate/ Eastern Asia	1884, IT	AT, BG, CH, DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MT, NL, PL, PT, RO, SI, UA	I2	*Euonymus*	Targioni Tozzetti (1884)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Unaspis yanonensis (Kuwana, 1923)	A	Phyto-phagous	Asia-Tropical	1969, FR	ES, FR, FR-COR, IT	I, I2	*Citrus*	Bénassy (1969)
Eriococcidae								
Eriococcus araucariae Maskell, 1879	A	Phyto-phagous	Australasia/ Australia	1895?, IT	ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, PT, PT-AZO, PT-MAD	I2	*Araucaria*	Leonardi (1899)
Eriococcus coccineus Cockerell, 1894	A	Phyto-phagous	Northern-America	1930, FR	FR,FR-COR, GR, HR, IT, IT-SIC	I2, J100	Cactaceae	Balachowsky (1932a)
Ovaticoccus agavium (Douglas, 1888)	A	Phyto-phagous	Northern-America	1888, GB	FR, FR-COR, IT, IT-SIC, UA	I2, J100	Agavaceae	Green (1915)
Margarodidae								
Icerya formicarum Newsteadt, 1897	A	Phyto-phagous	Asia-Tropical	2001, FR	FR	I2	Polyphagous	Foldi (2001)
Icerya purchasi (Maskell, 1879)	A	Phyto-phagous	Australasia/ Australia	1900, IT	AL, CH, CY, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, RO, SI	I, I2	Polyphagous	Leonardi (1920)
Ortheziidae								
Insignorthezia insignis (Browne, 1997)	A	Phyto-phagous	Southerrn-America	1887, GB	AT, CH, CZ, DE, DK, ES-CAN, FR, GB, HU, HR, PT, PT-AZO, PT-MAD	I2, J100	Polyphagous	Douglas (1889)
Phoenicococcidae								
Phoenicococcus marlatti (Cockerell, 1899)	A	Phyto-phagous	North Africa	1930, FR	ES, FR, FR-COR, IT, IT-SIC, PT-MAD	I2	Palms	Balachowsky (1930)
Pseudococcidae								
Antonina crawi Cockerell, 1900	A	Phyto-phagous	Asia-Tropical	1937, FR	ES, FR, GB, HR, UA	I2	Poaceae	Goux (1937)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Antonina graminis (Maskell, 1897)	A	Phyto-phagous	Asia-Tropical	1992, IT	FR, IT	E, I2	Poaceae	Marotta (1992)
Balanococcus diminutus (Leonardi, 1918)	A	Phyto-phagous	Australasia/ Australia	1918, IT	FR, GB, IT, UA	J100	*Phormium*	Leonardi (1918)
Balanococcus kwoni Pellizzari & Danzig 2007	A	Phyto-phagous	Asia	Last 2007,IT	IT	I2	Bamboos	Pellizzari and Danzig (2007)
Chaetococcus bambusae (Maskell, 1892)	A	Phyto-phagous	Asia-Tropical	1990, IT	IT	I2	Bamboos	Porcelli (1990)
Chorizococcus rostellum (Lobdell, 1930)	A	Phyto-phagous	Northern-America	1979, GR	FR, GR, HU, IT, IT-SAR	E, I	Agavaceae, Gramineae	Tranfaglia (1981)
Delottococcus euphorbiae (Ezzat & McConnell, 1956)	A	Phyto-phagous	Afrotropical/ South Africa	1977, IT	FR, IT, IT-SIC	I2	Polyphagous	Tranfaglia (1981)
Dysmicoccus boninsis (Kuwana, 1909)	C	Phyto-phagous	Cryptogenic	Last 1938 PT-MAD	PT-MAD	I	Polyphagous	Balachowsky (1938)
Dysmicoccus brevipes (Cockerell, 1893)	A	Phyto-phagous	Central-America	1933, NL	ES-CAN, IT, IT-SIC,NL, PT-AZO, PT-MAD	J100	Polyphagous	Jansen (1995)
Dysmicoccus grassii (Leonardi, 1913)	A	Phyto-phagous	Central-America	Last 1913 ES-CAN	ES-CAN, FR	I, J100	Polyphagous	Leonardi (1913)
Dysmicoccus mackienziei Beardsley 1965	A	Phyto-phagous	Southern-America/ Mexico	1989, IT	IT	I2	Bromeliaceae	Marotta (1992)
Dysmicoccus neobrevipes Beardsley 1959	A	Phyto-phagous	Southern-America	1988, NL	IT, IT-SIC, NL	I2	Polyphagous	Jansen (1995)
Ferrisia virgata (Cockerell, 1893)	A	Phyto-phagous	Southern-America	1994, NL	FR, NL	I2, J100	Polyphagous	Jansen (1995)
Geococcus coffeae Green, 1933	A	Phyto-phagous	Asia-Tropical	1967, NL	DK, FR, NL	I2, J100	Polyphagous	Jansen (1995)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Hypogeococcus pungens Granara de Willink, 1981	A	Phyto-phagous	Southern-America	1986, IT	FR, FR-COR, GR, IT, IT-SIC	I2	Cactaceae	Süss and Trematerra (1986)
Nipaecoccus nipae (Maskell, 1893)	A	Phyto-phagous	Central-America	1917, GB	ES, ES-CAN, GB, IT-SIC, PT-MAD	I2, J100	Polyphagous	Green (1917)
Palmicultor palmarum (Ehrhorn, 1916)	C	Phyto-phagous	Cryptogenic	2004, FR	ES-CAN, F	J100	Palms	Chapin and Germain (2005)
Peliococcus serratus (Ferris, 1925)	A	Phyto-phagous	Northern-America	1976, IT	IT	G, I2	*Corylus*	Tranfaglia (1976)
Phenacoccus gossypii Townsend & Cockerell, 1898	A	Phyto-phagous	Northern-America	1946, ES	ES, ES-CAN	I2	Polyphagous	Gómez-Menor Ortega (1946)
Phenacoccus madeirensis Green, 1923	A	Phyto-phagous	Southern-America	1923, PT-MAD	FR, IT, IT-SIC, PT-MAD	I2	Polyphagous	Green (1923)
Phenacoccus solani Ferris, 1918	A	Phyto-phagous	Northern-America	1999, IT, IT-SIC	AL, IT, IT-SIC	I2	Polyphagous	Mazzeo et al. (1999)
Planococcus citri (Risso, 1813)	A	Phyto-phagous	Asia-Tropical	1813, FR	BG, CH, CY, CZ, ES, ES-CAN, FR, FR-COR, GB,GR, HU, HR, IT, IT-SAR, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, SI, UA	I2, J100	Polyphagous	Risso (1813)
Planococcus halli Ezzat & McConnel, 1956	C	Phyto-phagous	Cryptogenic	1989, IT	IT	I2	*Nerium oleander*, Polyphagous	Marotta (1992)
Pseudococcus calceolariae (Maskell, 1879)	A	Phyto-phagous	Australasia/ Australia	1914, GB	BG, CZ, ES, ES-CAN, FR, FR-COR, GB, HR, IT, IT-SAR, IT-SIC, PT, PT-AZO, UA	I2, J100	Polyphagous	Green (1915)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pseudococcus cosmtocki (Kuwana, 1902)	A	Phyto-phagous	Asia-Temperate	last 1989, MD	ES-CAN,FR, IT, MD, PT-MAD	I, I2	Polyphagous	Ben-Dov (1994)
Pseudococcus longispinus (Targioni TozzettIT, 1868)	A	Phyto-phagous	Australasia/ Australia	1867, IT	BG, CZ, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, LV, MT, PT, PT-AZO, PT-MAD, PL, SI, UA	I2, J100	Polyphagous	Targioni Tozzetti (1886), (1885)
Pseudococcus viburni (Signoret, 1875)	A	Phyto-phagous	Northern-America	1875, FR	B, BG, DE, DK, CZ, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MT, NL, PT, PT-AZO, PT-MAD, PL, SI, SK, RS, UA	I, I2	Polyphagous	Signoret (1875)
Rhizoecus americanus (Hambleton, 1946)	A	Phyto-phagous	Northern-America	1992, IT, IT-SIC	IT, IT-SIC	I2	Polyphagous	Russo and Mazzeo (1992)
Rhizoecus cacticans (Hambleton, 1946)	A	Phyto-phagous	Southern-America	1961, NL	BY, CZ, DK, ES-CAN, IT, IT-SIC, NL, PL	I2	Polyphagous	Jansen (1995)
Rhizoecus dianthi Green, 1926	A	Phyto-phagous	Australasia/ Australia	1961, NL	CZ, DK, FR, IT, NL, PL	I2	Polyphagous	Jansen (1995)
Rhizoecus latus (Hambleton, 1946)	A	Phyto-phagous	Southern-America	1995, IT	IT	I2	Polyphagous	Marotta (1995)
Spilococcus mamillariae (Bouché, 1844)	A	Phyto-phagous	Northern-America	1979, IT	CZ, DE, DK, FR, GB, HU, IT, IT-SIC	I2, J100	Cactaceae	Tranfaglia (1981)
Trionymus angustifrons Hall, 1926	A	Phyto-phagous	Arabian peninsula	1966, PL	CH, FR, PL	E, I2	Compositae, *Tamarix, Urtica*	Koteja and Zak-Ogaza (1966)
Trochiscococcus speciosus (De Lotto, 1961)	A	Phyto-phagous	Afrotropical	1990, IT	FR,IT	J100	Liliaceae	Williams and Pellizzari (1997)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Vryburgia amaryllidis (Bouché, 1837)	A	Phyto-phagous	Afrotropical	1933, IT	BG, DE, ES, FR,GR, IT, NL, P	I2	Polyphagous	Menozzi (1933)
Vryburgia brevicruris (McKenzie, 1960)	A	Phyto-phagous	Afrotropical	1975, DK	BE, DK, GB	I2	Polyphagous	Kozarzhevskaya and Reitzel (1975)
Vryburgia rimariae Tranfaglia, 1981	A	Phyto-phagous	Afrotropical/ South Africa	1975, IT	FR, IT, IT-SIC	I2	Crassulaceae	Tranfaglia (1981)

Table 9.3.2. List and main characteristics of the scale species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 29/05/2009

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Diaspididae						
Aonidiella tinerfensis Lindinger (1911)	Phytophagous	Canary Islands	PT	I2	*Dracaena*	Balachowsky (1948), Fernandes (1992), (1990)
Aonidiella lauretorum (Lindinger, 1911)	Phytophagous	Canary Islands, Madeira	PT	I2	Polyphagous	Balachowsky (1948)
Margarodidae						
Marchalina hellenica (Gennadius, 1883)	Phytophagous	Greece, Turkey	IT	G	*Pinus*	Tranfaglia and Tremblay (1984)
Matsucoccus feytaudi Ducasse 1941	Phytophagous	France, Spain, Portugal	IT, FR-COR	G	*Pinus pinaster*	Arzone and Vidano (1981), Jactel et al. (1996)

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Other Hemiptera Sternorrhyncha (Aleyrodidae, Phylloxeroidea, and Psylloidea) and Hemiptera Auchenorrhyncha Chapter 9.4

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Abstract

Apart from aphids and scales, 52 additional Sternorrhyncha hemipteran species alien to Europe have been identified within Aleyrodidae (27 whitefly species), Phylloxeroidea (9 adelgids, 2 phylloxerans) and Psylloidea (14 species of jumping plant-lice) in addition to 12 Auchenorrhyncha species (mostly Cicadellidae- 8 species). At present, the alien species represent 39% of the total whitefly fauna and 36% of the total adelgid fauna occuring in Europe. The proportion is insignificant in the other groups. The arrival of alien phylloxerans and adelgids appeared to peak during the first part of the 20th century. In contrast, the mean number of new records per year of alien aleyrodids, psylloids and Auchenorrhyncha increased regularly after the 1950s. For these three groups, an average of 0.5–0.6 new alien species has been recorded per year in Europe since 2000. The region of origin of the alien species largely differs between the different groups. Alien aleyrodids and psylloids mainly originated from tropical regions whilst the adelgids and phylloxerans came equally from North America and Asia. A major part of the alien Auchenorrhyncha originated from North American. Most of these alien species are presently observed in man-made habitats, especially in parks and gardens but alien adelgids are mainly observed in forests because of their association with conifer trees used for afforestation.

Keywords
alien, Europe, Adelgidae, Aleyrodidae, Cicadellidae, Psyllidae, Phylloxeridae, Auchenorrhyncha

9.4.1. Introduction

This chapter will consider the hemipteran species alien to Europe belonging to the Sternorrhyncha superfamilies other than Aphidoidea and Coccoidea (i.e., Aleyrodoidea, and superfamilies Phylloxeroidea and Psylloidea) and to the Auchenorrhyncha (Cicadomorpha and Fulgoromorpha suborders). We will mainly follow the higher classification used in Fauna Europaea (Asche and Hoch 2004, Nieto Nafria and Binazzi 2005).

Both **Aleyrodoidae** (whiteflies) and **Psylloidea** (jumping plant-lice or psylloids) are distributed throughout the major zoogeographical regions of the World, with their greatest diversity in tropical and south temperate regions. They are all sap-sucking insects and most of them are narrowly host-plant specific. This is particularly true for the psylloids were such specificity may also be present at higher taxonomic levels and not just at species level. Both adult whiteflies and psylloids possess a feeding rostrum, two pairs of flying wings and are fully mobile. Reproduction in both groups is generally sexual with some rare cases of *parthenogenetic** development. The eggs in both groups are laid directly onto the host-plant surface.

Whiteflies comprise a relatively small group of insects in a unique family Aleyrodidae, and we will later us only this family name. Whiteflies are the least speciose among the four groups of sternorrhynchous Hemiptera (whiteflies, aphids, jumping plant-lice and scale insects) with only 1,556 described species accommodated in 161 genera (Martin and Mound 2008). Adult whiteflies are very small insects, most measuring between 1–3 mm in body length. Life-cycles of whiteflies are somewhat unusual. The first-instar larvae are able to walk around (crawler) short distances on the host plant until a suitable feeding site is found; then, the remaining three larval instars are sessile. The final whitefly larval stage is usually termed as a *puparium** where feeding goes on during the first part of this stage. It is also this stage which is used for almost all whitefly taxonomy and systematic with adults being identified only rarely. All whitefly species are free living during their larval stages.

Jumping-plant lice (Psylloidea) comprise some 3,000 described species accommodated in the six currently recognized families. Adults range from 1–12 mm in body length. Life-cycles of psylloids are very straightforward with eggs laid singly or in clusters on the host plant, the immatures undergoing five larval instars (being all mobile unless gall-dwelling) and after these adults emerge. In jumping-plant lice, both adults and nymphal stages are used for species identifications. More than three-quarters of psylloid species are free-living during their larval stages, but some are gall-inducing and others live under protective scales or lerps (waxy constructions covering the body).

The feeding activity of whiteflies and psylloids may negatively affect the host-plant by rendering weakness and thus more susceptibility to other diseases. The feeding activity of these insects (especially in whiteflies) may produce copious honeydew which may cover underlying leaves and fruits/flowers of the host-plant. Usually, this honeydew is immediately covered by black sooty mould which impairs photosynthesis and/or renders unmarketable plant parts such as flowers and fruits. Notorious pest species in both groups (adults) are vectors of a number of plant pathogens such as viruses and phytoplasmas.

Phylloxeroidea (adelgids and phylloxerans) is a closely related superfamily, which include some of the most destructive introduced plant pests in the World. They include minute insects (1–2 mm in body length), which are highly host specific but with a simple morphology. The two groups are distinguished from typical aphids (Aphididae) by the complete absence of *siphunculi** and the retention of the ancestral trait of oviparity in all generations. Phylloxerans feed on angiosperms, particularly hickories and ashes (Juglandaceae), oaks and beeches (Fagaceae) and grapes (Vitaceae) but adelgids only develop on certain genera of the Pinaceae family, retaining their ancestral relationships with gymnosperms. Such as their host plants, adelgids are endemic to the Northern Hemisphere in boreal and temperate habitats. Despite the broad geographical distribution of these host plants, there are less than 70 and ca. 75 species of known adelgids and phylloxerans, respectively (Havill and Foottit 2007). However, there is considerable taxonomic uncertainty in both groups since several described species may not represent unique taxa but are actually different morphological forms of the same species found on different host plants. Both groups exhibit cyclical parthenogenesis and possess complex, multigenerational, polymorphic life cycles. Five generations make up the typical two- year adelgid *holocycle**, three produced on the primary host, *Picea* spp. (noticed as -I- in Table 9.4.1) where sexual reproduction and gall formation occurs, and the last two are produced on a secondary host (*Abies*, *Larix*, *Pseudotsuga*, *Tsuga*, or *Pinus,* noticed as -II- in Table 9.4.1) which supports a series of asexual generations. Adelgids that are *anholocyclic** complete their entire life cycle on either *Picea* or on a secondary host genus. Some anholocyclic species may in fact be holocyclic, but forms on the alternate host have not been described. Typically, sexual reproduction and host alternation nymphs and galls are formed in spring. Winged *gallicolae** can disperse or can stay to lay eggs near the gall from which they emerged.

Auchenorrhyncha, with some 42,000 described species worldwide is probably paraphyletic but composed of two well supported monophyletic groups, **Fulgoromorpha** (planthoppers) and **Cicadomorpha** (leafhoppers, froghoppers, treehoppers and cicadas). Hemipteran phylogeny is still controversial (Cryan 2005, Yoshizawa and Saigusa 2001) although Sternorrhyncha, Fulgoromorpha, Cicadomorpha, Coleorrhyncha and Heteroptera are considered monophyletic by most authors (Bourgoin and Campbell 2002, Dietrich 2002, Nielson 1985). Auchenorrhyncha usually feed on plant sap, either on phloem, xylem or parenchyma, and they occur therefore in almost all habitats colonized by vascular plants. Many are of economic importance due to the transmission of phytopathogenic organisms causing plant diseases such as phytoplasmas and virus diseases (Bourgoin and Campbell 2002, Carver et al. 1991, Dietrich 2005, Kristensen 1991, Nielson 1985). Most Auchenorrhyncha have a bisexual reproduction. Eggs are usually laid into plant tissue and there are 5 nymphal instars. While some species are good flyers and can be carried by wind over relatively long distances (Della Giustina and Balasse 1999), most of the translocations are considered due to anthropogenic causes. All the species introduced from North American and east Asiatic are assumed to have been imported with plants, either as eggs in the tissue or as nymphs or adults feeding on the host plants.

Planthoppers (Fulgoromorpha) with 21 families and some 12,000 described species occur worldwide but are most diverse in the tropics. Only the widely distributed families Cixiidae and Delphacidae occur also in colder regions such as Northern Europe. In Europe, ca. 750 species of Fulgoromorpha are expected to occur (Asche and Hoch 2004). They can be distinguished by the following characters: pedicel of antenna bulbous or enlarged; presence of *tegulae** on the mesothorax; bases of mid-coxae widely separated. The body size varies from 2–114 mm but most species are small (O'Brien and Wilson 1985).

Cicadomorpha are characterised by following characters: antennal pedicel small; tegulae absent; meso-coxae small and narrowly separated. To date, 30,000 species of Cicadomorpha have been described in over than 5,000 genera and 13 families. Dietrich (Dietrich 2002) estimated that about 6–10% of plant-feeding insects belong to the Cicadomorpha. Despite their economic importance, there are surprisingly still many gaps in the knowledge on the taxonomy, phylogeny, life history and biology of Auchenorrhyncha.

9.4.2. Taxonomy and invasion history of the Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha alien to Europe

The literature about alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha in Europe is relatively scattered, most of the studies dealing with alien pests of economic importance such as *Bemisia tabaci* and *Trialeurodes vaporarium* (Bedford et al. 1994, Martin et al. 2000) for Aleyrodidae or *Metcalfa pruinosa* and *Scaphoideus titanus* (Arzone et al. 1987, Dlabola 1981) for Auchenorrhyncha. Indeed, comprehensive data on alien species were available for only a few European countries. i.e., Albania, Bulgaria and Macedonia (Tomov et al. 2009), Austria (Essl and Rabitsch 2002), the Czech Republic (Šefrová and Laštùvka 2005), Germany (Geiter et al. 2002), Great Britain (Hill et al. 2005), Slovenia (Seljak 2002) and Switzerland (Kenis 2005). The 'Handbook of alien species in Europe' (DAISIE 2009), generated by the DAISIE project, listed a number of species alien to Europe (i.e, of exotic origin or cryptogenic) and alien in Europe (introduced by man from a European region to another where the species is not native) but the status of some of these species also needed to be reviewed. At the end of each group, we provide information on the species of this group we excluded from the alien list either because of confusion in their actual status or of misidentifications. Apart from the established species, the alien lists of Aleyrodidae, Phylloxeroidea and Psylloidea will also include species which were observed only in greenhouses and for which no data is available on their establishment in the wild in the mentioned territory. In contrast, the list of alien Auchenorrhyncha will only include established species in the wild.

9.4.2.1 Aleyrodidae

A total of 27 species alien *to* Europe were recorded. Although the family Aleyrodidae include three subfamilies only two of these are represented in both the alien and the native European fauna. At present, the alien species represent 39% of the total whitefly fauna observed in Europe (Figure 9.4.1). Twenty alien species belong to Aleyrodinae, which is the most widespread and largest subfamily with over 1,400 described species. Seven species belong to the subfamily Aleurodicinae, which is mainly confined to South America, plus very few species in South-Eastern Asia and other geographical regions (121 described species) (Martin 1996). It is usually regarded as being more primitive than Aleyrodinae. In general, Aleurodicinae represent much larger species than typical whitefly, their additional wing venation being possibly a functional necessity associated with their large size. The pupal cases of the Aleurodicinae are generally more complex than those of the Aleyrodinae, bearing large compound wax-secreting pores on the dorsal surface. Species of whiteflies intercepted in greenhouses (occasionally or once) are rather few. Such species were included in the list because additional introductions as well as establishment in the wild are not to be excluded especially under global change conditions. These species include *Filicaleyrodes williamsi*, a species whose origin remains obscure; *Aleuropteridis filicicola,* an African species found on ferns; *Aleurotulus nephrolepidis*, a specialist fern feeder often found in greenhouses which is already known to occur in the wild in Macaronesia (Martin et al. 2000); *Ceraleurodicus varus*, an Aleurodicinae species which was found to colonize orchids in 1939- 1940 in an orchid house at the Budapest Botanical Garden, but was never intercepted again or recorded in other European countries; *Aleurodicus destructor* of which a single specimen was collected from *Olea* at a Garden Festival in Liverpool, UK, but which is occasionally intercepted by quarantine inspections in Europe (Martin 1996); a neotropical whitefly, *Aleurotrachelus trachoides* was intercepted in Great Britain on sweet potato leaves imported from Gambia (Malumphy 2005); and, *Pealius azaleae*. This latter species is often regarded as a minor pest of ornamental azaleas (*Rhododendron* spp.). It was originally described from Belgian material intercepted by quarantine officials in the United States but its origin is likely Eastern Asia. The occurrence of this species in Europe is very sporadic and records often reflect newly introduced populations with azalea hosts being kept indoors, in greenhouses or in very sheltered places.

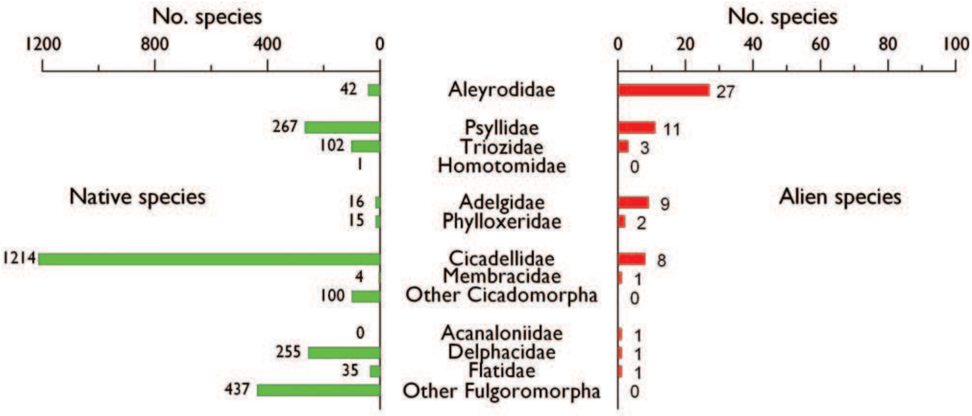

Figure 9.4.1. Comparison of the relative importance of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha in the alien and native entomofauna in Europe. The number right to the bar indicates the number of species per family.

An emergent whitefly pest in Europe is *Alerocanthus spiniferus*, commonly known as the Orange Spiny Whitefly. This species is listed as a quarantine threat to Europe and is included in the EPPO A1-List of species recommended for regulation as quarantine pests and in the EU Annex II/A1 under: "Pests known not to occur in the EU, whose introduction into, and/or whose spread within, all EU Member States is prohibited, with reference to specific plants or plant products". The accidental introduction, acclimatization and spreading of this species in southern Italy (Porcelli 2008) is thus of concern to all the European Union. As pointed out by Porcelli (Porcelli 2008), the origin of the infestation of this species is still unknown, and the species has already spread in the Apulia Region to make its eradication impossible. *A. spiniferus* is a widespread tropical species, occasionally a pest on *Annona* and *Citrus*, but it is also recorded from woody hosts of more than 15 plant families (Martin 1996). *Aleuroclava aucubae*, a species described from Japan and most likely of Oriental origin, was recently recorded from Italy (Pellizari and Šimala 2007) and may also prove to be a potential pest in Europe. It is known to occur on more than 15 plant families (Mound and Halsey 1978) and in the Veneto region, the species was found on both greenhouse plants (*Citrus x limon* (L.) Osb., *Ficus sycomorus* L.) and outdoor host plants (*Pittosporum tobira* (Thunb.) Aiton , *Prunus armeniaca* L., *Photinia*).

Some whitefly species not native to Europe have been found in Macaronesia and some of these are also penetrating into Europe. *Aleuroplatus perseaphagus* is a species of Neotropical origin, but was first described from Madeira. The species is common on avocado. *Aleurotrachelus atratus* is also a species of Neotropical origin, but was found in the Canary Islands (Martin et al. 2000) and is now being recorded on several endangered palm species on various islands in the south-western Indian Ocean and in glasshouses in Paris (Borowiec et al. 2010). *Acaudaleyrodes rachipora* was described from India and is probably native to Asia but the species is also known from the Canary islands (Martin et al. 2000). *Crenidorsum aroidephagus*, introduced in Madeira, is a native of New World, colonising several plant species of the Araceae family in Central and South America, southern USA, and the Pacific Region. It is is also reported as a minor pest for growers of ornamental-foliage plants (Martin et al. 2001).

Massilieurodes chittendeni is most probably a species originating from northern Asia, from where its host plant, rhododendrons, mainly originate. This species was described on material collected in England in 1928 (Laing 1928). Klasa et al. (2003) reported the introduction of this species to central Poland, the Czech Republic, Germany and the Netherlands. Two whitefly species with an uncertain area of origin include *Dialeurodes kirkaldyi* and *Singiella citrifolii* both potential pests of *Citrus*-plantations. *D. kirkaldyi* was originally described from Hawaii and later reported in several states in North America (Russell 1964). The species is also known from Africa and Asia. In Europe it was so far found in Cyprus and Portugal. *S. citrifolii* was originally described from the United States. It is known from the Oriental Regions and from the Neotropics and the Nearctic Region. In Europe the species is known from Madeira (Aguiar 1998) and recently it was reported from the Mediterranean Region (Lebanon) (Martin 2000). *Parabemisia myricae*, commonly known as the Japanese bayberry whitefly, is probably native to Japan. It arrived in the Mediterranean Basin and Southern Europe in the mid 1980s and in a very short time it invaded most of the Mediterranean countries with considerable damage to citrus plantations (Rapisarda et al. 1990).

Some alien whitefly species show little dispersion in Europe. *Trialeurodes packardi*, a species native to the Nearctic Region where it is extremely polyphagous, was only noted in Hungary (Kozár et al. 1987) as a pest on strawberries. *T. packardi* is closely related to *T. vaporariorum*, and the two species can only be distinguished via microscopic examination of pupal cases, and this may also be a reason why the species was not recorded elsewhere in Europe.

A highly polyphagous Neotropical species is *Aleurodicus dispersus*, commonly known as the Spiralling Whitefly. This species is occasionally detected in northern Europe on plants imported from the Far East (Martin 1996). In the 1970s this species began a rapid expansion of its range, westwards from the New World, and crossed the Pacific to the Philippines by 1983, and in 1990 its arrival in the Malay Peninsula was noted. Since then its spread continued into Thailand, Sri Lanka, southern India, the Maldive Islands, and Western Africa (Martin 1996). Its establishment in the Canaries dates back to the early 1960s, but the species is also known from Macaronesia where it is common on trees and shrubs in the open and seems to be a well established species. A species which co-exists with *A. dispersus* in the Canary Island is *Lecanoides floccissimus*, a second Neotropical species which is particularly damaging to numerous unrelated host-plants due to direct feeding and by the enormous populations depriving plants of sap and thus inhibiting growth. The species is also known to secrete copious honeydew on which sooty mould immediately grows and a final effect to people living in the area where this species is abundant, is the fluffy white "wool" secreted by the larval stages, which blows from trees, sticks to clothing and garden furniture, and even causes allergic reactions (Martin et al. 1997). The genus *Paraleyrodes*, also native to the

Neotropical Region, is represented in the West Palaearctic by three species. *Paraleyrodes* species are all very small, comparable in size to members of the Aleyrodinae, and similarly having their fore wing venation reduced to a single unbranched main vein. However, the larval instars all possess wax-producing pores of compound structure, claws on the puparial legs and a quadrisetose *ligula**, all being diagnostic characteristics for the Aleurodicinae. *P. bondari*, is well established in Madeira with material collected on several host-plants since 1995 and likelwise*, P. citricolus,* established on the same island at least since 1994 and is common on both *Citrus* spp. and *Persea americana* Miller (Martin 1996). *P. minei*, although originally described from Syria, is native to the Neotropics. This species has been established in Spain since the early 1990s where it provokes substantial damage on citrus plantations (Garcia Garcia et al. 1992). A fourth species, *P. pseudonaranjae* Martin has become established in Florida, Hawaii, Bermuda and Hong Kong and seems to be rapidly extending its native geographical range (Martin 2001). This species is polyphagous with *Citrus* included in its host-plant records and Europe should be alerted with respect to the high risk of introducing this species.

With regard to the DAISIE list of alien Aleyrodidae published in the 'Handbook of alien species in Europe'(DAISIE 2009), the identification of *Aleuroclava guyavae* by Pellizari and Šimala (Pellizari and Šimala 2007) was incorrect and should refer to *A. aucubae*, a closely related species (Martin, J. pers. comm., 2010). *Bemisis afer* (Priesner & Hosny) was not included as an alien species to Europe in this work as this group is in need of taxonomic revision. Several samples from Britain do however come from glasshouses and its status in Britain was reviewed by Malumphy (2003). Besides, several forms are known from Macaronesia, and before a proper revision of the group is done to define species boundaries no account on European material is included. *Aleurolobus marlatti* (Quaintance) was also removed from the list of alien species in Europe. The species has a very wide geographical distribution with native records from Southern Europe (Sicily and Malta). We also excluded *Aleurolobus olivinus* (Silvestri), a species which is widely found in Europe and wherever its preferred host-plant (olive tree) grows. Finally, *Dialeurodes formosensis* Takahashi was also excluded because the unconfirmed record to species level of Iaccarino (1985) was incorrect and should refer to *Dialeurodes setiger* (Goux), a species native of the Mediterranean area.

9.4.2.2 Psylloidea

Jumping plant-lice alien *to* Europe include 14 species belonging to two families, Psyllidae (11 species) and Triozidae (3 species) (Figure 9.4.1). The Psyllidae family is the largest family of jumping lant-lice with a cosmopolitan distribution and some 1,800 described species accommodated in more than 150 genera. As presently constituted this family is difficult to define as, effectively, it comprises all those species that do not belong in any other of the five psylloid families. The family has a wide range of host-plants with many species utilising woody legumes. Some species are gall-inducers and all of the solitary lerp-forming species belong to this family. The genus *Acizzia* currently accommodates more than 30 described species of psylloids mainly found in Australia, New Zealand, the Old World tropics and extending through North Africa and the Middle East to the Mediterranean Basin (Hodkinson and Hollis 1987). Among other characteristics, male adults of this genus have a *proctiger** with a conspicuous posterior lobe, forewing with a tapered pterostigma and distinct costal break, basal metatarsus with 1 or 2 black spures and apical segment of aedeagus often complex. Species feed on mimosoid legumes, particularly *Acacia* and *Albizia*. In Europe, four species are considered alien introductions. *Acizzia hollisi* was described from Saudi Arabia and Israel (Burckhardt 1981) on *Acacia raddiana* Savi and was found on the island of Lampedusa in 1987 (Conci and Tamanini 1989). *Acizzia acaciaebaileyanae* and *A. uncatoides* were originally described from Australia and New Zealand, respectively. Both species have been introduced and established in several European locations; *A. acaciaebaileyanae* in France (Malausa et al. 1997), Italy (Fauna Italia, Rapisarda 1985) and Slovenia (Seljak et al. 2004) whereas *A. uncatoides* in France, Italy, Portugal (Hodkinson and Hollis 1987), Montenegro (Lauterer 1993), Malta (Mifsud 2010) and the Canary Islands. Within this psylloid group, the latest arrival in Europe was *Acizzia jamatonica*, originally described from Asia. This species was first noted in Italy (Zandigiacomo et al. 2002), and it was later recorded from a number of European countries including France and Corsica (Chapin and Cocquempot 2005), Slovenia (Seljak 2003), Switzerland (Kenis 2005), Croatia (Seljak et al. 2004), and Hungary (Redel and Penzes 2006). Since 2006, this species was also introduced in the Nearctic Region and its occurrence in the south-eastern United States was surveyed (Wheeler Jr and Richard Hoebeke 2009).

Another group of psylloids which are being accidentally introduced and established in Europe are those associated with eucalyptus plantations. The psylloid subfamily Spondyliaspidinae represents a group of insects associated with Myrtaceae, in particular with eucalyptus. Eucalypts, native to Australia, are planted for a variety of uses in many warmer regions throughout the Old and the New World. The commercial value of selected species for the production of ornamental foliage used in the cut flower industry and/or for pulp timber production has resulted in the widespread planting of *Eucalyptus* trees. Psylloids associated with such host-plants, have become established outside their native range and are sometimes responsible for severe damage to such plantations (Burckhardt and Elgueta 2000). One such psylloid is *Blastopsylla occidentalis* described from Australia, New Zealand and California, and subsequently reported from Mexico, Brazil and Chile (Burckhardt and Lauterer 1997). The species was recently reported in Italy (Laudonia 2006) and most likely this psylloid is already established in other Mediterranean countries. *Glycaspis brimblecombei,* commonly known as the Redgum Lerp Psyllid, originally described from Brisbane in Australia, is also expanding its range with records from Mauritius and California (late 1990s), and it has recently been intercepted in Spain and Portugal (Valente and Hodkinson 2008). The Redgum Lerp Psyllid is becoming a major ornamental pest of Red Gum Eucalyptus, but also occurs on Sugar Gum, Glue Gum and other *Eucalyptus* spp. Three species of *Ctenarytaina* also established in Europe, the first being *C. eucalypti*, commonly known as the Eucalyptus psyllid. Originally described from specimens collected on blue gum in New Zealand, this species was first introduced into southern England, northern France and South Africa as early as the 1920s (Laing 1922, Mercier and Poisson 1926, Pettey 1925). This psylloid pest expanded and its current distribution includes France, Germany, Italy, Portugal, Madeira, the Azores, Spain, the Canary Islands, Switzerland and Great Britain (Hodkinson 1999, Wittenberg 2005). The two other species of *Ctenarytaina* have been introduced more recently. *C. spatulata* was first reported from France and Italy (Costanzi et al. 2003) and later from Portugal (Valente et al. 2004) and Spain (Mansilla et al. 2004), whereas C. *peregrina* was first intercepted and described from England (Hodkinson 2007) and recently reported from France and Italy (Cocquempot and Constanzi (Unpubl.)).

The genus *Cacopsylla* includes more than 100 described species distributed mainly in the Holarctic Region, with species that penetrate the Oriental, Afrotropical and Neotropical Regions. Cocquempot and Germain (Cocquempot and Germain 2000) recorded *Cacopsylla fulguralis*, a species native to western Asia, for the first time from France and subsequently the species was found in Belgium (Baugnée 2003), Italy (Süss and Salvodelli 2003), Spain (Cocquempot 2008), Switzerland (Cantiani 1968) and the United Kingdom (Malumphy and Halstead 2003). *Cacopsylla pulchella*, a species strictly associated with the Juda's tree (*Cercis siliquastrum* L.) is probably native to the Eastern Mediterranean basin but since the 1960s the species was found in various localities in Central and Northern Europe (Cantiani 1968, Hodkinson and White 1979b).

The family Triozidae is the second largest family of Psylloidea with some 1,000 described species accommodated in 50 poorly diagnosed genera (Hollis 1984) with a worldwide tropical/temperate distribution. Species utilise host plants in a wide variety of families but never on legumes and many species produce characteristic galls on their host-plants. Four species are recorded as alien for Europe. *Trioza neglecta* was introduced to Europe from south-western and Central Asia, the area of its origin, with its host plant, *Elaeagnus angustifolia* L. grown as an ornamental shrub in parks and along roads. It is now widely distributed from Georgia, Armenia, Azerbaijan, Iran and Anatolia through Russia, Ukraine, Moldavia, Bulgaria, the former Yugoslavia and Romania to Central Europe (Hungary, Slovakia, the Czech Republic, Austria) (Lauterer and Malenovský 2002b). The other two introduced triozid psylloids include *T. erytreae* and *T. vitreoradiata*, both of economic importance and which are treated in detail under section 9.4.8. An additional triozid species, *Bactericera tremblayi* (Wagner), was included in the list of aliens of the DAISIE 'Handbook of alien species in Europe' (DAISIE 2009) but was removed from the present list. This species was abundant in Southern Italy and caused problems on onions since the late 1950s. However, around 1980 the populations of this species declined and now the species seems to be rare and localised. According to Tremblay (1988) the species could have been a recent introduction in Italy from the former USSR. There is not much to sustain such a statement given the fact that apart from Italy, the species is known to occur in Switzerland, France, Turkey, Iran and questionably from Syria and also because the species is polyphagous on herbaceous plants (Burckhardt and Mühlethaler 2003, Lauterer et al. in prep).

In addition, several other psylloid species can be considered as alien *in* Europe. One is a species from the small Homotomidae family, which includes 80 described species in the world, accommodated in 11 genera. Host plants all belong to the Moraceae family, and mainly to the genus *Ficus*. Most known larvae are free-living, although some live in colonies under communal lerps and very few species are gall-inducers. Most species have a pan-tropical distribution but *Homotoma ficus* (L.), a native of Central-Southern Europe and the Middle East feeding on *Ficus carica* L., has been introduced in Southern England where it seems to be confined (Hodkinson and White 1979a). It is alien to North America (Hollis and Broomfield 1989).

In the same category of alien *in* Europe are two Psyllidae species. *Calophya rhois* (Löw), a southern-European species, was reported as introduced in Britain on the basis of a single record from Scalpay in the Hebrides (Hodkinson and White 1979a). The genus *Calophya* is species-poor and distributed in the Neotropical, Holarctic and Oriental Regions with jumping plant-lice associated mainly with Anacardiaceae. *Livilla variegata* (Löw), is probably native to Eastern Europe. The species is known from France, Italy, Switzerland, Bosnia, Romania, Spain, Great Britain, Hungary, Germany, Austria and the Czech Republic (Hodkinson and White 1979b, Lauterer and Malenovský 2002b). This species is strictly oligophagous on *Laburnum anagyroides* Medik. and *L.. alpinum* (Mill.) Bercht. & Presl., and it is already a widespread element in Central Europe, where it colonises its host plant, *L. anagyroides*, an introduced Mediterranean ornamental tree commonly planted in parks and gardens, towns and villages and on roadsides. The introduction and spread of *L. variegata* in Central Europe escaped the notice of entomologists, similar to what happened in England, where it was collected for the first time in 1978 (Hollis 1978), but by which time it was already widespread in that country. A last species, *Trioza alacris* Flor, is most likely of Mediterranean origin but was introduced throughout central and Northern Europe (only in greenhouses or on laurels placed temporarily outside during summer) on cultivated bay laurel. It mostly develops on Laurel (*Laurus nobilis* L.) but is also reported on *L. azoricus* Seub., producing characteristic large leaf galls by rolling the leaf margins down to the lower leaf surface. Most probably the earliest record in Central Europe was that of Schaefer (1949) with material collected from Switzerland in 1917. The species was also introduced in USA (California and New Jersey), Brazil, Chile and Argentina (Conci and Tamanini 1985).

9.4.2.3. Phylloxeroidea

– Adelgidae

Following the 2007 revision by Havill and Footit (2007), a total of 9 adelgid species were identified as alien *to* Europe, including 6 species in the genus *Adelges* (subgenera *Cholodovskaya*, *Dreyfusia*, and *Gilletteella*) and 3 species in the genus *Pineus* (subgenera *Pineus* and *Eopineus)*. At present, these alien species represent 36% of the total adelgid fauna observed in Europe (Figure 9.4.1). Most of them were introduced during the late 19th century- early 20th century alongside with their exotic conifer host trees which were massively used at that time for afforestation in Europe, e.g. Douglas-fir (*Pseudotsuga menziesii* Mirb. (Franco)) for *Adelges cooleyi* (Chrystal 1922) and *A. coweni* (Roversi and Binazzi 1996), Caucasian fir (*Abies nordmanianna* Spach.) for *Adelges (Dreyfusia) nordmanianna* (Marchal 1913) , *A. prelli* (Eichhorn 1967) and *A. merkeri* (Binazzi and Covassi 1988), and oriental spruce, *Picea orientalis* (L.) Link., for *Pineus orientalis*. Some other species were introduced along with ornamental trees originating from North America such as *Pineus* (*Eopineus*) *strobi* with the eastern white pine, *Pinus strobus* (Steffan 1972), and *Pineus similis* with Sitka spruce, *Picea sitchensis* (Bong.) Carrière (Carter 1975, Carter 1975). A majority (five out of nine) of the alien species are holocyclic, one is anholocyclic of first type developing entirely on *Picea* (*Pineus similis*) and three anholocyclic of second type developing entirely on *Pseudotsuga* (*Adelges coweni*), *Larix* (*A. viridula*) or *Pinus strobus* (*Pineus strobi*).

In addition, several adelgid species native of the Alps and/or Central Europe can be considered as alien *in* Europe. Their primary host is mostly spruce (*Picea*), and then larch (*Larix*), fir (*Abies*), or pine (*Pinus*). They include *Adelges (Adelges) laricis* Vallot, which accompanied the plantations of larch in the lowlands (Glavendekić et al. 2007, Hill et al. 2005), and several species introduced from continental Europe to Great Britain, i.e. *Adelges (Adelges) piceae* Ratzeburg, *A. (Sacchiphantes) abietis* L. , *A. (Sacchiphantes) viridis* Ratzeburg , and *Pineus pineoides* Cholodkovsky (Hill et al. 2005). Similarly, the alpine *Pineus cembrae* (Cholodokovsky) colonized the Faroe islands with Swiss stone pine, *Pinus cembra* L. *Adelges (Aphrastasia) pectinatae* (Cholodkovsky), a species which develops on spruce and fir was first considered as an alien in Europe (DAISIE 2009) having established in Central and Northern Europe, including the Baltic countries (Gederaas et al. 2007, Holman and Pintera 1977). However, its origin is difficult to be ascertained since Havill and Footit (2007) indicated 'Europe, China and Japan'.

– *Phylloxeridae*

There are two species of phylloxerans alien *to* Europe with regard to 15 native species (Figure 9.4.1). *Moritziella corticalis* is of unknown origin (cryptogenic) and was first reported as introduced in Britain (Barson and Carter 1972). The genus *Moritziella* accommodates two species living on Fagaceae. They are distinguished from Palaearctic species of *Phylloxera* by the absence of abdominal spiracles on segment 2–5 and by the presence of numerous well-developed, pigmented dorsal tubercles. Generic distinction between North American species of *Phylloxera* and *Moritziella* is however not satisfactory.

The other species is the well-known 'Phylloxera', *Viteus vitifoliae* (=*Dactylosphaera vitifoliae*) which has devastated the European vineyards at the end of 19th century. The genus *Viteus* is a monotypic genus, the *alatae** of which have paler abdominal *stigmal** plates and a shorter distal *sensorium** on the third antennal segment than the common

European *Quercus*-feeding *Phylloxera*. *Viteus vitifoliae* typically goes through a two-year cycle involving a sexual phase and leaf-galling and root-feeding stages on American vines. On European vines it normally lives continuously on the roots, reproducing parthenogenetically. Leaf-galls occur in Europe on cultivars derived from hybrids between *Vitis vinifera* L. and American vines. The economic significance of this species is discussed in some detail under section 9.4.8.

9.4.2.4. Auchenorrhyncha

A total of 12 species alien *to* Europe have been considered (Figure 9.4.1). Not surprisingly most of them belong to the species- rich family of Cicadellidae (17,000–20,000 worldwide; 1,236 species in Europe). Other families are represented only by a single species in each.

Within Cicadomorpha, the Cicadellidae (leafhoppers) is the largest family with 50 subfamilies and 17,000–20,000 described species. Leafhoppers live in all zoogeographical regions and feed on a wide range of host plants, though individual species have often trophically and geographically restricted ranges (Dolling 1991, Nielson 1985). Cicadellidae varies in body length from 2–30 mm. Leafhoppers feed on a large range of plants (grasses, herbaceous plants, trees and shrubs). The majority of leafhoppers feed on phloem, some on xylem (especially the subfamily Cicadellinae), and only members of the subfamiliy Typhlocybinae are specialised parenchyma-feeder. Leafhoppers are well known vectors of plant diseases and of economic importance worldwide. For some leafhopper species migratory behaviour is documented (Della Giustina 2002). Eight leafhopper species are certainly alien to Europe. Probably most famous is the Rhododendron leafhopper, *Graphocephala fennahi*, a native to North America. The species was first reported from southern England in the 1930s but it crossed the Channel only after 1960, to the Netherlands from where it spread rapidly within continental Europe. Two other North American species, *Scaphoideus titanus* and *Erythroneura vulnerata*, are pest species on grapes. Especially *Scaphoideus titanus* has become an important pest since it is the vector of 'flavescence dorée' phytoplasma to grapevine. The Neartic leafhopper *Kyboasca maligna* does not seem to be problematic as an alien species to Europe for the time being. From Eastern Asia four cicadellid species have been introduced: *Japananus hyalinus*, *Macropsis elaeagni*, *Orientus ishidae* and *Igutettix oculatus*. None of them have yet been found to transmit plant diseases in Europe and are therefore not of economic importance. *O. ishidae* was only recently reported new to Europe (Günthart et al. 2004) but is spreading rapidly in Europe (Switzerland, Italy, Germany, Slovenia, France, Austria, Czech Republic). *I. oculatus* (=*Vilbasteana oculata* (Lindberg)) is originally an eastern Palaearctic species which was first found in Moscow in 1984 and is now spreading to the west (Finland (Söderman 2005)). It lives on *Syringa*.

With around 3,200 described species Membracidae is the largest family of treehoppers. Membracids are widespread worldwide but only few species occur in Europe. This family is most diverse in the Neotropics and North America. Characteristic is the enlarged pronotum with sometimes bizarre shaped extensions and elongations. They are medium sized with a body length of 2–24 mm. As with other members of Cicadomorpha, Membracidae lay their eggs into living plant tissue. If populations are too big this can cause serious damages to the host plant and therefore can be regarded as crop pests (e.g. apple trees, see e.g. (Arzone et al. 1987)). Only four species are native to Europe. One species (*Stictocephala bisonia*) was introduced from North America.

The Fulgoromorpha group yet contributed for only three species alien to Europe, with one per family Delphacidae, Flatidae and Acanaloniidae, to be compared to 727 species native in Europe. Delphacidae are characterized by a moveable spur on the hind tibia. Species are generally small (2–6 mm) and are widely distributed also in colder regions. Worldwide around 1,500 delphacid species are described. They feed on monocotyledons and are economically important as pest species on rice, maize, wheat and sugarcane. *Nilaparvata lugens* (Stål) for example is a serious pest of rice in Asia (O'Brien 2002, Wilson and Claridge 1991). In Europe there are some 260 species. Only one alien delphacid has established in Europe, *Prokelisia marginata*, which was first found on the Algarve (Portugal) in 1994 and in Spain in 1998 (unpublished data M.R. Wilson). In Slovenia a well established population was found in 2004 (Seljak 2004). New, unpublished records are from southern England (2008) and France (2009). It is very likely that this planthopper is expanding its range rapidly along the European coasts.

Species of the family Flatidae have often colourful opaque wings and can be distinguished from other Fulgoromorpha by the numerous parallel crossveins along the costal margin of the forewing and a single spine at each side of the second tarsomere of the hind leg. The body size varies between 4.5–32.0 mm. Flatids feed on different shrubs, trees and herbs (O'Brien 2002). The North American *Metcalfa pruinosa* has been introduced to Europe probably in plant material and was first recorded in Italy in 1983. From there it is spreading rapidly to the rest of southern Europe (France, Slovenia, Switzerland, Austria, the Czech Republic) causing damages on grapes (Della Giustina 1986, Dlabola 1981, Holzinger et al. 1996, Lauterer and Malenovský 2002a, Mani and Baroffio 1997, Seljak 2002).

The Acanaloniidae is a small family of Fulgoromorpha with c. 80 described species accommodated in 14 genera. In general they resemble flatid planthoppers. This family is not native to Europe and the north American species *Acanalonia conica* was only recently introduced into northern Italy (D'Urso and Uliana 2006). *A. conica* has a similar biology to *Metcalfa pruinosa* and can often be found in mixed nymphal feeding groupings with the latter (Wilson and MacPherson 1981). Therefore this species could potentially be another pest insect for European vineyards.

Tropiduchidae is a small family within the Fulgoromorpha with some 400 described species worldwide. Body size varies between 5–13 mm; the mesonotum with its apical angle is separated by a transverse groove. They feed on ferns, palms, grasses and Dicotyledonae (O'Brien 2002). *Ommatissus lybicus* Bergevin, the dubas bug, was for a long time regarded as a variety of *O. binotatus* Fieber (but see Asche and Wilson 1989). *O. lybicus* is a severe pest of date palms in the Middle East causing the death of trees. *O. binotatus* was described from Spain and feeds on *Chamaerops humilis* L. It was also found in Sicily and Portugal and is a native European species and should be deleted from the DAISIE list.

Species with an Eurosiberian or a Holarctic distribution, *Edwardsiana ishidai* Matsumura and *Kyboasca bipunctata* (Oshanin), have been excluded from Table 9.4.1. Other leafhopper species with a doubtful alien status include: *Cicadulina bipunctata* (Melichar), a North African species which occurs also in the eastern Mediterranean; *Empoasca punjabensis* Singh-Pruthi, originally described from India but is also reported from the southern parts of European Russia , Ukraine, Bulgaria, Serbia and Greece; *Jacobiasca lybica* (Bergevin & Zanon), another North African species which is reported from other Mediterranean regions (Sicily, Sardinia and Greece); *Melillaia desbrochersi* (Lethierry), a North African species also reported from Greece, Sicily and Corsica; *Psammotettix saxatilis* Emeljanov, described from Kazakhstan and found in France but possibly conspecific with *P. sierranevadae* Dlabola from Spain.

There are some papers reporting mainly records of Mediterranean Auchenorrhyncha new to Northern European regions (Maczey and Wilson 2004, Nickel and Holzinger 2006, Wilson 1981). Due to lack of sufficient historical information on the distribution of most Auchenorrhyncha species it is difficult to determine if anthropogenic factors and/or climatic influence are the main causes of range extension. There are for example some southern European *Eupteryx* species, which appear to have become in the last decades more common in central Europe or even extended their range to northern latitudes such as Denmark and the UK. These species may exploit certain man made habitats, e.g. in greenhouses where herbal plants are cultivated (such as Lamiaceae e.g. *Melissa*, *Oreganum*, etc.) but may also build up localised 'wild' populations. Such populations may be stable over years under good environmental conditions but can also easily break down depending on several conditions including weather, pressure of predators, parasites and others. Continental European Auchenorrhyncha species introduced to European islands are also excluded of this overview. Thus, five Cicadellidae species (*Empoasca pteridis* (Dahlbom), *Grypotes puncticollis* (Herrich-Schaffer), *Iassus scutellaris* (Fieber), *Placotettix taeniatifrons* (Kirschbaum) and *Wagneripteryx germari* (Zetterstedt)) are reported to be alien in the UK (Stewart 1993). On the other hand it is very likely that *Philaenus spumarius* L. (Aphrophoridae) was introduced into Iceland in the late 1970s.

9.4.3 Temporal trends of introduction in Europe of alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

The first records in Europe are approximately known for 60 of the 64 species considered here. Dates given are relatively imprecise, as most of these tiny species have probably been introduced several years before they were reported.

The number of new records per time period largely differed among Aleyrodidae, Psylloidea, Phylloxeroidea and Auchenorrhyncha (Figure 9.4.2.). The arrival of alien phylloxerans and adelgids appeared to peak during the first part of the 20[th] century. Some species such as the Grape Phylloxera, *Viteus vinifoliae*, and the silver fir adelgid, *Adelges nordmannianae*, arrived earlier in the 19[th] century but most species, especially the ones associated with Douglas-fir (*Adelges cooleyi* and *A. coweni*) were probably introduced in the early 1900s. Only one new species having been introduced later (*Pineus simi*lis in 1971), and apparently none during the last ten years.

In contrast, the mean number of new records per year of Aleyrodids, Psylloids and Auchenorrhyncha increased regularly from the 1950s. For these three groups, an average of 0.5–0.6 new alien species has been recorded per year in Europe since 2000. The first documented introduced alien Auchenorrhycha to Europe was *Stictocephala bisonia* (at that time under the name *Ceresa bubalus*) in eastern Europe (former Austro-Hungarian Empire) in 1912 (Horvaáth 1912). This treehopper was probably introduced with fruit tree cuttings and is now widespread all over Europe except the northern regions. It was followed by another North American species, *Graphocephala fennahi*, which was first found on rhododendrons in southern England in 1933. Since then other Auchenorrhyncha species from North America or East Asia have been introduced mainly to Central or Southern Europe benefiting from international trade of plants. In the case of *Scaphoideus titanus* it seems that this species had a first ancient introduction followed by multiple colonization events (Bertin et al. 2007).

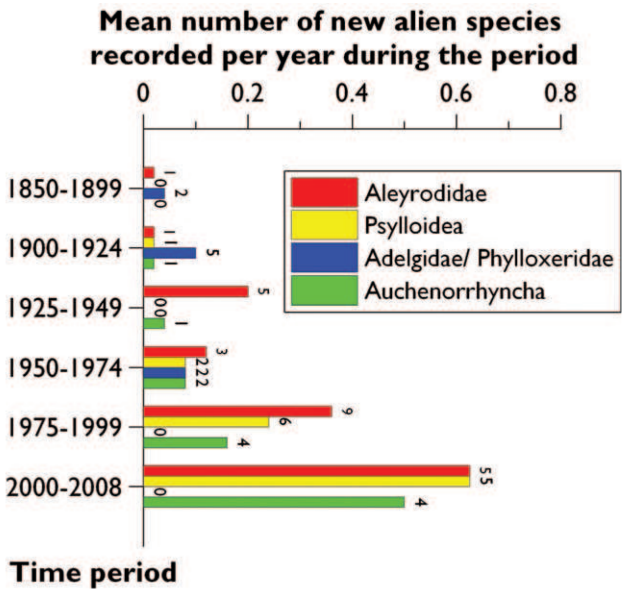

Figure 9.4.2. Temporal changes in the mean number of new records per year of Aleyrodidae, Psylloidea, Phylloxeroidea (Adelgidae/ Phylloxeridae) and Auchenorrhyncha alien *to* Europe from 1800 to 2009. The number right to the bar indicates the total number of species recorded per time period.

9.4.4 Biogeographic patterns of the Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha alien to Europe

9.4.4.1 Origin of alien species

The region of origin of the alien species largely differs between groups (Figure 9.4.3). Aleyrodids and psylloids mainly originated from tropical regions, the Neotropics and Australasia, respectively. Adelgids and phylloxerans came equally from North America and Asia, mostly because a number of adelgids were introduced from the Caucasus Mountains together with their conifer hosts. In contrast, most of the alien Auchenorrhyncha have a North American origin. For a few species, the area of origin remains uncertain.

9.4.4.2 Distribution of alien species in the European countries

For whiteflies and psylloids, the distribution of alien species to Europe or to certain parts of Europe has been highlighted and documented in 9.4.2 and is also presented in Table 9.4.1. Most of the alien species of aleyrodids, psylloids, phylloxerans and adelgids did not spread largely within Europe yet. Indeed, 31 species out of 52 (i.e., 60%) have colonized less than five European countries. Only 4 species, two aleyrodids (*Bemisia ta-*

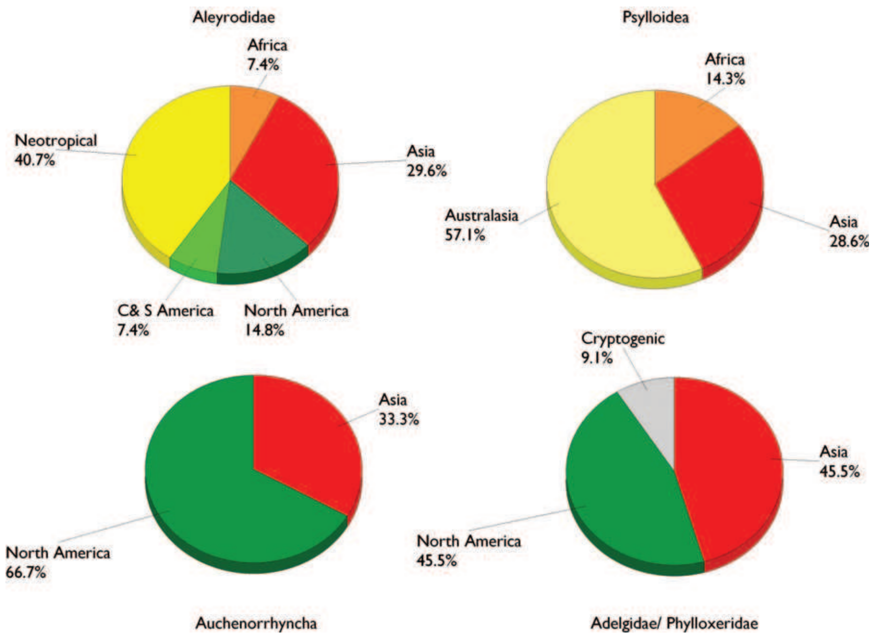

Figure 9.4.3. Comparative origin of the Aleyrodidae, Psylloidea, Phylloxeroidea (Adelgidae/ Phylloxeridae) and Auchenorrhyncha species alien *to* Europe

baci and *Trialeurodes vaporariorum*), one phyloxeran (*Viteus vinifoliae*) and one adelgid (*Adelges nordmannianae*) have colonized more than 20 countries (Table 9.4.1).

Due to the lack of comprehensive data we cannot give appropriate information on the distribution of alien Auchenorrhyncha in Europe. However three species (*Scaphoideus titanus*, *Metcalfa pruinosa* and recently *Acanalonia conica*) could have first established in the Mediterranean region from where they spread northbound. Other species expanded their range from eastern Europe (*Stictocephala bisonia*, *Macropsis eleagni*) or central Europe (*Japananus hyalinus*, *Orientus ishidae*), one species started from the UK (*Graphocephala fennahi*). It is also possible that some of the alien species had multiple introductions (*Scaphoideus titanus*, *Prokelisia marginata*). Generally the introduced species could spread easily as long as the environmental conditions are appropriate for them (climate, host plants, etc.). Five out of the 12 alien species spread in more than 10 countries, with *Stictocephala bisonia* having expanded in 26 countries and islands (Table 9.4.1).

9.4.5 Pathways of introduction to Europe of the alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

Most alien species of whiteflies, psylloids, phylloxerids and adelgids were accidentally introduced with their host plant. In most circumstances such introductions occurred via trade of the host plant or of parts of the host plants such as fruit or cut flowers.

It is reported that Auchenorrhyncha can migrate. Usually they are short-distance migrants to leave non-permanent habitats but some species are able to migrate over long distances (Della Giustina 2002). The probably most amazing example is the cicadellid *Balclutha pauxilla* Lindberg which invaded in swarms the Ascension Island in the Atlantic Ocean (about half way between South America and Africa) in 1976. The specimens must have flown more than 2,000 km over the sea probably coming from Africa (Ghauri 1983).

Despite of the fact of possible migration, alien Auchenorrhyncha certainly profit of the worldwide trade of fruit trees, vine cuttings and ornamental plants. Especially eggs in the plant tissue can survive the transport even over long distances and time. Once arrived, the nymphs hatch and without their specific parasites they can build up strong populations. Not surprisingly some alien Auchenorrhyncha were first found around harbours (e.g. *Prokelisia marginata*) or cities (*Orientus ishidae*), an unmistakable trace of their pathway of introduction.

9.4.6 Ecosystems and habitats invaded in Europe by the alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

Apart from those species so far intercepted only in greenhouses and of which no reports exist of their establishment in Europe, the other introduced species of the five groups treated in this account are often confined to few related host plants. For example, several species of whiteflies which in their area of origin are highly polyphagous have shown to be strictly oligophagous in their new territories, occurring mainly on Citrus and some other woody hosts.

Thus, the major part of these alien species is presently observed in man-made habitats, especially in parks and gardens where a number of exotic plants have been planted (Figure 9.4.4). Natural and semi-natural habitats are yet little colonized by alien Auchenorrhyncha and psylloids (<20%) and quite none by aleyrodids. A noticeable exception concerns adelgids because of their association with conifer trees used for afforestation. More than 60% of the alien adelgids are thus found in forest habitats together with fir, spruce and larch trees.

Interestingly so far only one grassland species (*Prokelisia marginata*) was introduced to Europe. This species lives originally in salt marshes along the East-Coast of North America and is associated with *Spartina* grasses. All other alien Auchenorrhyncha colonize mainly anthropogenic habitats (vine yards, orchards, gardens, parks). Some of them are polyphagous and can therefore also be found in natural environments (e.g. *Stictocephala bisonia* in dry habitats or *Orientus ishidae* on willows and birch trees).

9.4.7 Ecological and economic impact of the alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

In terms of economic losses, the two most important whiteflies in Europe are *Trialeurodes vaporariorum*, commonly known as the glasshouse or greenhouse whitefly and *Bemisia tabaci,* commonly known as the Cotton Whitefly. *T. vaporariorum* is a member of a North American species-group. It was however described in 1856 from England, at which time the species was an already widespread and established pest. *B. tabaci*,

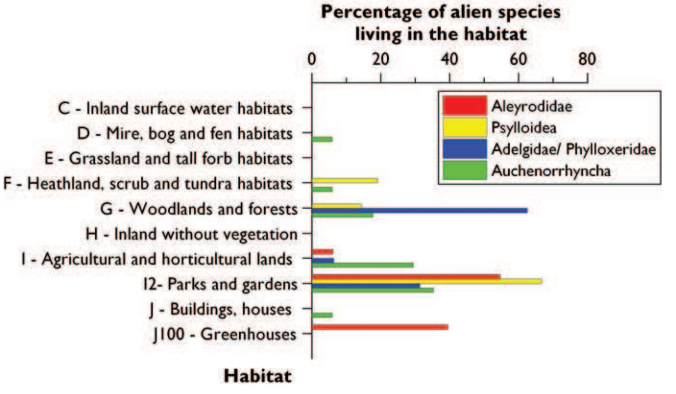

Figure 9.4.4. Main European habitats colonized by the established alien species of Aleyrodidae, Psylloidea, Phylloxeroidea (Adelgidae/ Phylloxeridae) and Auchenorrhyncha. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

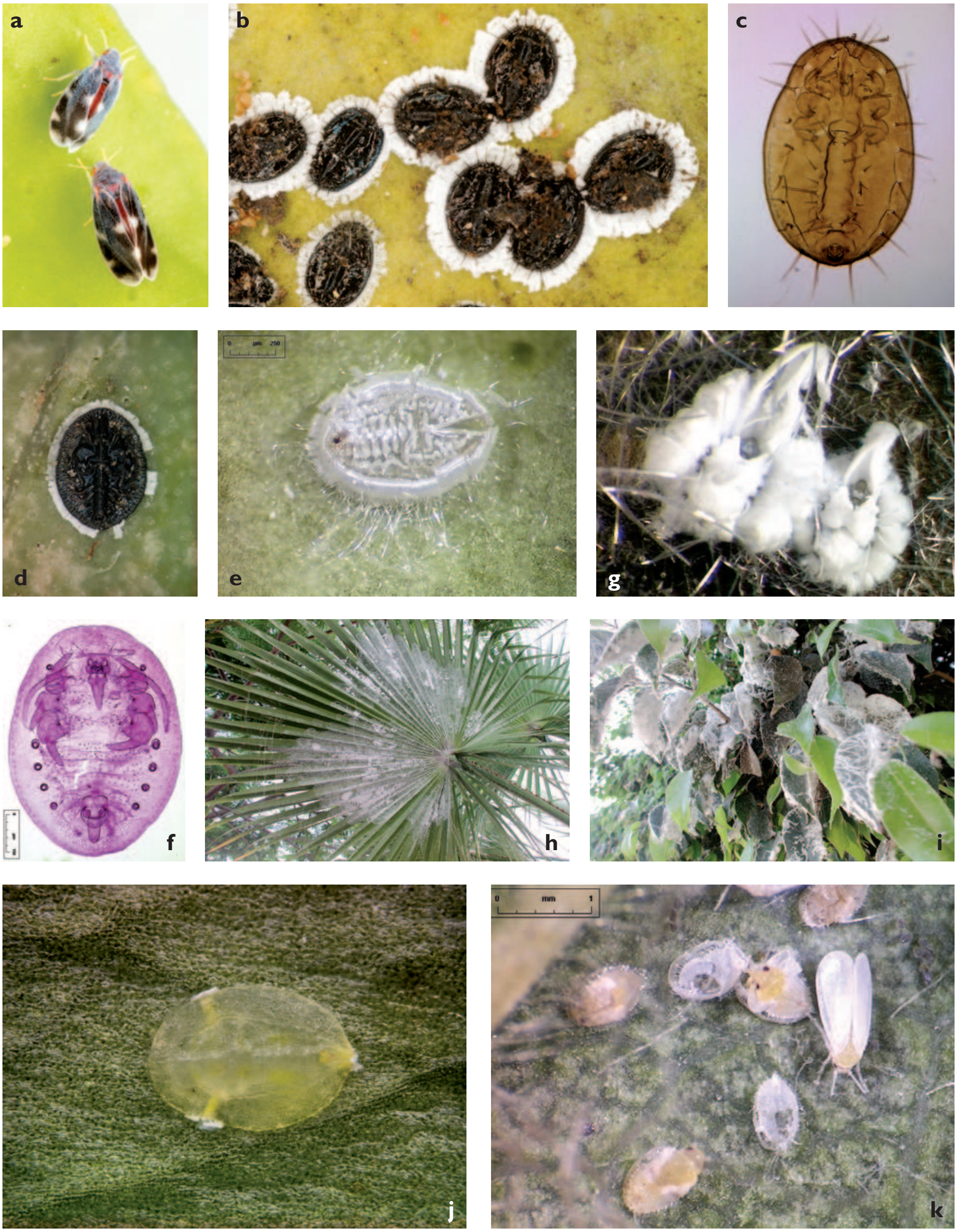

Figure 9.4.5. Aleyrodid species alien *to* Europe. **a** *Aleurocanthus spiniferus* adult **b** *Aleurocanthus spiniferus* puparium **c** *Aleurocanthus spiniferus* puparium from palm leaf (East-Timor) **d** *Acaudaleyrodes rachipora* puparium on leaf of *Argania* (Agadir, Morocco) **e** *Aleurothrixus floccosus* puparium on leaf of *Citrus reticulata* (France) **f** *Aleurodicus dispersus* puparium from leaf of *Psidium gajava* (Martinique) **g** *Aleurodicus dispersus* puparium on leaf of *Psidium gajava* (Martinique) **h** *Aleurodicus dispersus* damage on palm leaf **i** *Aleurodicus dispersus* damage on leaf **j** *Bemisia tabaci* from Thailand intercepted at Roissy airport, France on leaf of *Eryngium foetidum* **k** *Trialeurodes vaporariorum* adults and puparium on leaf of *Fragaria* (France). (Credit: **a, b, h, i** - Francesco Porcelli; **c, d, e, f, g, j, k** - LNPV Montpellier).

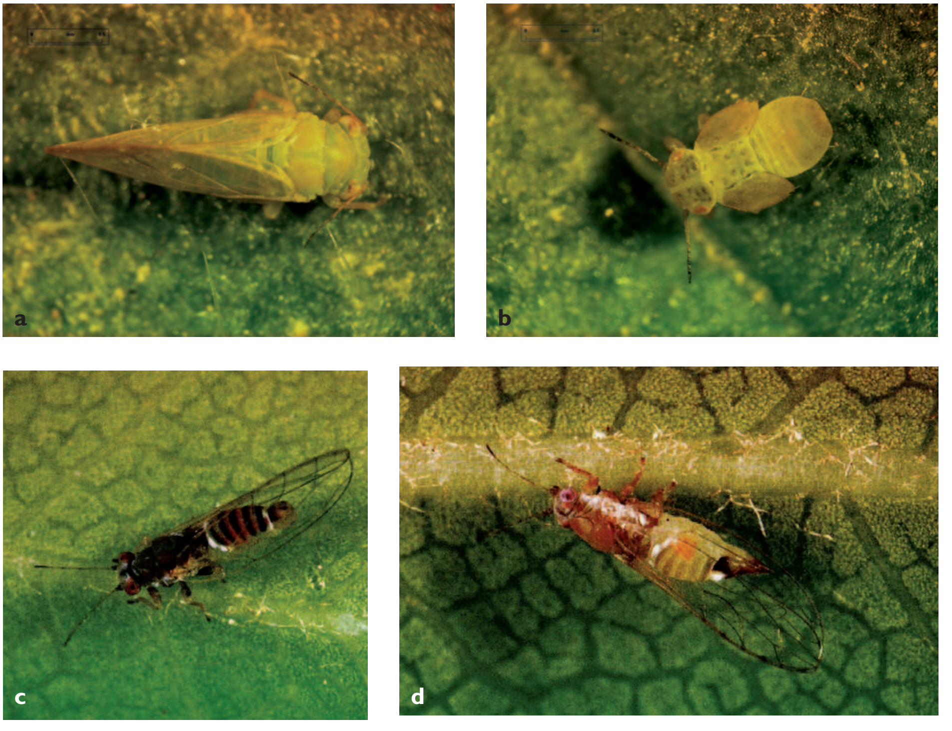

Figure 9.4.6. Psylloid species alien *to* Europe. **a** *Acizzia jamatonica* adult on leaf of *Albizia* (Bordeaux, France) **b** *Acizzia jamatonica* immature on leaf of *Albizia* (Bordeaux, France) **d** *Trioza vitreoradiata* male under a leaf of *Pittosporum tobira* **e** *Trioza vitreoradiata* female. (Credits: **a, b** - LNPV Montpellier; **c, d** - Jean-Marie Ramel and Christian Cocquempot).

probably of Asian origin, is now virtually cosmopolitan, usually found under glass in areas with continental climates. Several biotopes of this species are known (De Barro et al. 1998) and this taxon is known to transmit geminiviruses to cultivated plants of various unrelated groups (Bedford et al. 1994) and is a serious pest of both open-air and protected cropping. Some of the "emerging" whitefly pests in Europe may also prove to be of high economic impact to European agriculture and within this group the most promising species seems to be *Aleurocanthus spiniferus*.

One of the most important species of psylloid in terms of economic losses is *Trioza erytrea*, a native to the Afrotropical Region. This species is a major pest of citrus plantations, but in its native range is also known to develop on *Vepris undulata* (Thunb.) Verdoorn & C.A. Sm. *Zanthoxylum* (=*Fagara*) *capense* (Thunb.) Harvey and *Clausena anisata* (Willd.) Hook. f. ex Benth. (Hollis 1984). The main economic importance of *T. erytreae* is as vector of the citrus disease caused by citrus greening bacterium (also transmitted by the psylloid, *Diaphorina citri* Kuwayana). Both psylloids are listed as A1 quarantine pests by EPPO and other phytosanitary organisations. Isolated outbreaks of this species were first noted in Europe in Madeira in 1994 and it seems that the species is now established on both the Canary Islands and Madeira (Borges et al. 2008, Gonzalez

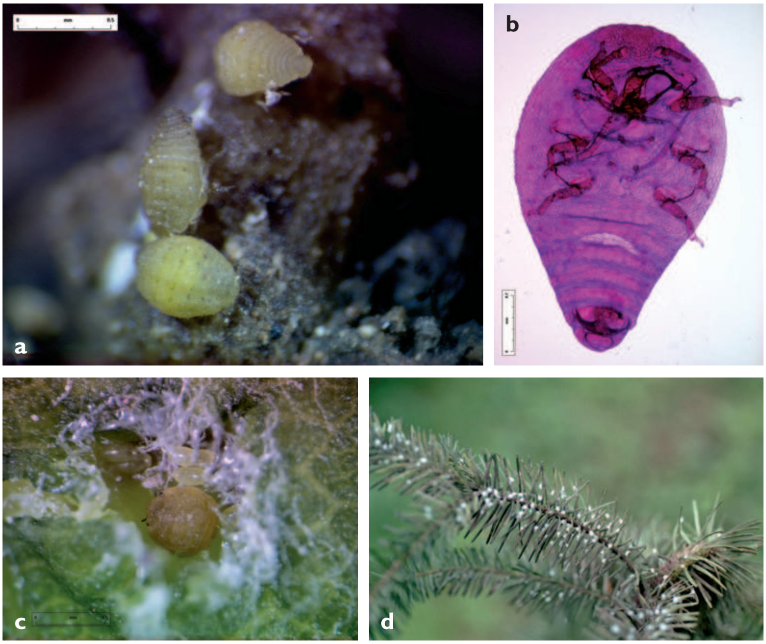

Figure 9.4.7. Adelgid and phylloxeran species alien alien *to* Europe. **a, b** - *Viteus vitifoliae* on roots of *Vitis vinifera* (France) **c** *V. vitifoliae* from galls on leaf of *V.vinifera* (France) (Credit: LNPV Montpellier) **d** *Adelges cooleyi* on needles of Douglas-fir (France) (Credit: A. Roques).

2003). *T. erytrea* is also a species of considerable taxonomic interest as it is part of a complex of species, all of which are difficult to define morphologically, but which have discrete host plant preferences (Hollis 1984). Another important psylloid of economic significance is *Trioza vitreoradiata*, a species native to New Zealand but recently established in Britain (Martin and Malumphy 1995), Ireland (O'Connor et al. 2004), and France (Cocquempot 2008). This psylloid is specific to *Pittosporum* where apart from direct loss by the plant in the form of sap depletion caused by the feeding activity of the psylloid, shallow pit galls are formed on young leaves, which remain visible for the life of the leaf. Sooty mould is also very common due to the large amounts of honeydew droppings on underlying leafs. The galling and presence of such sooty moulds make unmarketable ornamental plants of *Pittosporum tenuifolium* Gaertner, which are often grown for the cut-flower industry and also harvested for its foliage (Martin and Malumphy 1995).

Two of the introduced Auchenorrhyncha are of high economical importance. Both are regarded as pest species of vine. *Scaphoideus titanus* is a vector of 'flavescence dorée', a phytoplasma disease (grape vine yellows), which can cause big crop losses. *Metcalfa pruinosa* affects the plants directly. Strong populations can weaken the plant by sucking and the excreted honeydew is medium for fungi, which can cause reduction in the quality of the fruits.

The only phylloxerid of devastating economic significance and which was the cause of much trouble for the wine industry in Europe was the Grape Phylloxera, *Viteus vitifoliae*. This serious pest of grapes originated in North America where the local

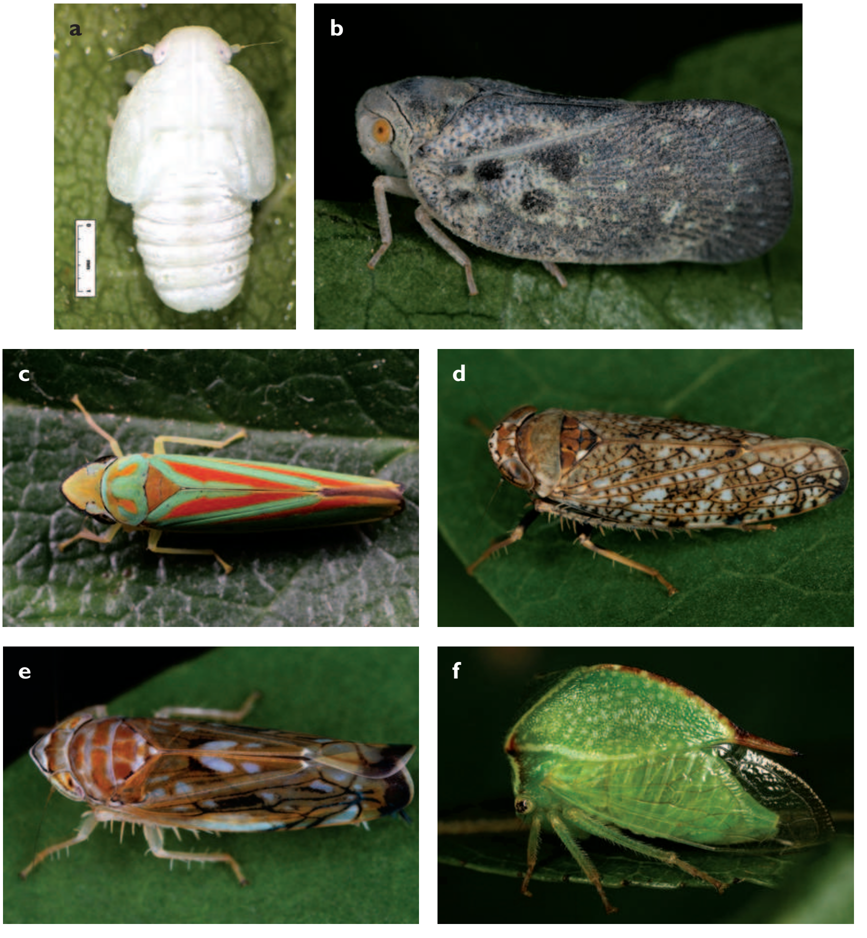

Figure 9.4.8. Auchenorrhyncha species alien *to* Europe. **a** *Metcalfa pruinosa* larvae **b** *Metcalfa pruinosa* adult **c** *Graphocephala fennahi* adult **d** *Orientus ishidae* adult **e** *Scaphoideus titanus* adult **f** *Stictocephala bisonia* adult. (Credit: **a** - LNPV Montpellier; **b–f** - Gernot Kunz)

vines evolved with it and are not severely damaged by its feeding activity. The species was accidentally introduced to Europe around 1860. In Italy, the species was first reported in 1879 and one year later it was also found in Sicily. In certain countries, possibly due to strict quarantine notices of this new pest, several years passed by before its introduction (e.g. in Malta, Grape Phylloxera was introduced in 1919 (Mifsud and Watson 1999)) but eventually the species was introduced everywhere. It invaded the Mediterranean Region, the Middle East, Africa, Korea, Australia, New Zealand and parts of South America. Grape Phylloxera feeds on species of *Vitis* including grape vines. Foliar attack does not seem to be unduly damaging, but asexual forms attacking roots all year round can kill plants that did not originate from North America. Grafting European vines onto North American rootstocks has successfully solved this problem in the past, but concern has increased in recent years because this resistance is being broken in some parts of the World as new biotypes of Grape Phylloxera are evolving (King and Rilling 1985).

9.4.8. Conclusion

Only few European countries produced comprehensive lists of alien Aleyrodidae, Psylloidea, Phylloxeroidea and Auchenorrhyncha. Most of these alien insects were probably introduced by plant material and once established could spread quickly into other European countries. Fortunately, only few species (*Trioza erythrea*, *Trioza vitreoradiata*, *Scaphoideus titanus*, *Metcalfa pruinosas* and *Stictocephala bisonia*) have to be regarded as pest or potential pest species so far. However, recent introductions (*Acanalonia conica*, *Orientus ishidae*, *Prokelisia marginata*) show that trade is the main factor of introduction and that at any time new problematic species can occur.

On the other hand we have still not sufficient information on the migration of Auchenorrhyncha within European regions. Several observations indicate that in the last decades Mediterranean species expanded their distribution to the North but it is not clear if they can establish wild populations or not. Usually these species profit from anthropogenic habitats (e.g. agricultural areas and parks) and can cause problems. Therefore we need to monitor species migration carefully.

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References

Aguiar AMF (1998) New records of whiteflies (Homoptera : Aleyrodidae) from Madeira Island with some taxonomic notes. *Boletim do Museu Municipal do Funchal* Suplemento 5: 9–26.

Aloi A. (1898) Un nuovo e serio pericolo per l'odierna viticoltura. *Agricoltore calabro-siculo*, 23: 229–230.

Anonymous (1894) Đrazprostranenie na filoksernata zaraza u nas. *Oralo* 1, 29–30, 234–236.

Arzone A, Vidano C, Alma A (1987) Auchenorrhyncha introduced into Europe from the Nearctic region: taxonomic and phytopathological problems. In Wilson MR, Nault LR (eds) *Proceedings of the 2nd International Workshop on leafhoppers and Planthoppers of Economic Importance*. London: CIE, 3–17.

Asche M, Hoch H (2004) *Fauna Europaea: Cicadomorpha*. Fauna Europaea version 1.1, available at http://www.faunaeur.org [accessed at 05.02.2010].

Asche M, Wilson M R (1989) The palm-feeding planthopper genus *Ommatissus* (Homoptera: Fulgoroidea: Tropiduchidae). *Systematic Entomology* 14: 127–147.

Barson G, Carter CI (1972) A species of Phylloxeridae, *Moritziella corticalis* (Kalt.) (Homoptera) new to Britain, and a key to the British oak-feeding Phylloxeridae. *Entomologist* 105: 130–134.

Baudyš E (1935) *Hospodářská fytopathologie.* [Economic phythopathology]. Brno, 630 pp.

Baugnée JY (2003) Sur la présence en Belgique du Cicadellidae *Kyboasca maligna* (Walsh, 1862) et du Psyllidae *Cacopsylla fulguralis* (Kuwayama, 1907) (Hemiptera Homoptera). *Bulletin de la Société royale belge d'Entomologie* 139: 72–73.

Bayer E (1914) *Moravské hálky (Zoocecidia)*. Pokorný a spol., Brno, 181 pp.

Bayer E (1920) *Synopsis zoocecidií středoevropských se zřetelem k zemím českým* [Synopsis of the Central-European galls with regard to the Czech country] Brno: Moravy Muzeum Zemské. 237 pp.

Bedford ID, Briddon RW, Brown JK, Rosell RC, Markham PG (1994) Geminivirus transmission and biological characterisation of Bemisia tabaci (Gennadius) biotypes from different geographical regions. *Annals of Applied Biology* 125: 311–325.

Bertin S, Guglielmino CR, Karam N, Gomulski LM, Malacrida A R, Gasperi G (2007) Diffusion of the Neartic leafhopper *Scaphoideus titanus* Ball in Europe: a consequence of human trading activity. *Genetica* 131: 275–285.

Binazzi A, Covassi M (1988) Le specie del Gen. *Dreyfusia* in Italia. Nota preliminare (Homoptera Adelgidae). *Atti del XV Congresso Nazionale Italiano di Entomologia*, L'Aquila, 267–273.

Borges PAV, Franquinho Aguiar AM, Boiero M, Carles-Tolra M, Serrano ARM (2008) Capítulo 10.1 - Lista dos Artrópodes (Arthropoda) in Borges PAV, Abreu C, Franquinho Aguiar AM, Carvalho P, Jardim R, Melo I, Oliviera P, Sergio C, Serrano ARM, Vieira P (eds.) *Listagem dos fungos, flora e fauna terrestres dos arquipélagos da Madeira e Selvagens, Secretaria Regional do Ambiente e dos Recursos Naturals do Governo regional da Madeira, Funchal*: 271–438.

Borowiec N, Quilici S, Martin J, Issimaila MA, Chadhouliati AC, Youssoufa MA, Beaudoin-Ollivier L, Delvare G, Reynaud B (2010) Increasing distribution and damage to palms by the Neotropical whitefly, *Aleurotrachelus atratus* (Hemiptera: Aleyrodidae). *Journal of Applied Entomology* 134 (in press).

Bourgoin T, Campbell BC (2002) Inferring a phylogeny for hemiptera: Falling into the 'autapomorphic trap'. *Denisia* 04: 67–82.

Burckhardt D (1981) Insects of Saudi Arabia. Sternorrhyncha: Suborder Psyllodea. *Fauna of Saudi Arabia* 3: 213–226.

Burckhardt D (1998) *Ctenarytaina eucalypti* (Maskell) (Hemiptera, Psylloidea) neu für Mitteleuropa mit Bemerkungen zur Blattflohfauna von *Eucalyptus*. *Mitteilungen der Entomologischen Gesellschaft Basel* 48: 59–67.

Burckhardt D, Elgueta M (2000) *Blastopsylla occidentalis* Taylor (Hemiptera: Psyllidae), a new introduced Eucalyptus pest in Chile. Revista Chilena de Entomología 26: 57–61.

Burckhardt D, Lauterer P (1997) A taxonomic reassessment of the triozid genus *Bactericera* (Hemiptera: Psylloidea). *Journal of Natural History* 31: 99–153.

Burckhardt D, Mühlethaler R (2003) Exotische Elemente der Schweizer Blattflohfauna (Hemiptera, Psylloidea) mit einer Liste weiterer potentieller Arten. *Mitteilungen der Entomologischen Gesellschaft Basel* 53: 98–110.

Cantiani M (1968) L'afide lanigero della Douglasia (*Gilletteella cooley* Gill.) in Italia. *L'Italia forestale e montana* 23, 195–198..

Carter CI (1983) Some new aphid arrivals to Britain's forests, *Proceedings and Transactions of the British Entomological and Natural History Society*, 16: 81–87.

Carter CI (1975) A gall forming adelgid (*Pineus similes* (Gill)) new to Britain with a key to the adelgid galls on Sitka spruce, *Entomologist's Monthly Magazine*, 111, 29–32.

Carver M, Gross GF, Woodward TE (1991) Hemiptera. InCSIRO (Ed) *The Insects of Australia*. Melbourne: Melbourne University Press, 429–509.

Chapin E, Cocquempot, C (2005) Psylle de l'Albizia: 1ers signalements en France. *PHM-Revue horticole* 467: 49–52.

China WE (1935) A North American Jassid (Homoptera) in Surrey. *Entomologist's Monthly Magazine* 71: 277–279.

Chrystal RN (1922) *The Douglas fir Chermes* (*Chermes cooleyi*). *Forestry Commision Bulletin No. 4*. London: His Majesty's Stationery Office. 50 pp.

Cocquempot C (2008) Un nouveau psylle sur pittospore du Japon en France. *PHM-Revue horticole*, 498: 33–36.

Cocquempot C, Constance, unpublished observations.

Cocquempot C, Germain JF (2000) Un nouveau ravageur de l'*Elaeagnus* x *ebbingei* en France : *Cacopsylla fulguralis*. *PHM-Revue horticole* 416: 32–34.

Conci C, Tamanini L (1985) *Lauritrioza* n. gen. for *Trioza alacris* (Homoptera Psylloidea). *Atti della Societa italiana di Scienze Naturali (Museo Civico di Storia Naturali di Milano*) 126: 237–256.

Conci C, Tamanini L (1989) *Acizzia hollisi*, new for Europe, and other psyllids from Isles Lampedusa and Linosa (Sicily) (Hemiptera, Homoptera). *Naturalista Siciliano* S. IV,13 (1–2): 75–80.

Costanzi M, Malausa JC, Cocquempot C (2003) Un nouveau psylle sur les Eucalyptus de la Riviera Ligure et de la Côte d'Azur. Premières observations de *Ctenarytaina spatulata* Taylor dans le Bassin méditerranéen occidental. *Phytoma – La Défense des Végétaux* 556: 48–51.

Covassi M, Binazzi A (1981) - Contributi alla conoscenza degli Afidi delle Conifere. IV, Note su alcune specie di Adelgidi reperite in Italia (Homoptera Adelgidae). *Redia* 64, 303–329.

Cryan JR (2005) Molecular phylogeny of Cicadomorpha (Insecta: Hemiptera: Cicadoidea, Cercopoidea and Membracoidea): adding evidence to the controversy. *Systematic Entomology* 30: 563–574.

DAISIE (2009) *Handbook of Alien Species in Europe*. Dordrecht:: Springer, 399 pp.

De Barro PJ, Liebregts W, Carver M (1998) Distribution and identity of biotypes of *Bemisia tabaci* (Gennadius) (Hemiptera : Aleyrodidae) in member countries of the Secretariat of the Pacific Community. *Australian Journal of Entomology* 37: 214–218.

Della Giustina W (1986) *Metcalfa pruinosa* (Say, 1830), nouveauté pour la Faune de France. *Bulletin de la Société Entomologique de France* 91: 89–92.

Della Giustina W (2002) Migration in Auchenorrhyncha. *Denisia* 04: 513–522.

Della Giustina W, Balasse H (1999) Gone with the wind: Homoptera Auchenorrhyncha collected by the French network of suction traps in 1994. *Marburger Entomologische Publikationen* 3: 7–42.

Della Giustina W, Remane R (2001) Compléments à la faune de France des Auchenorrhyncha: espèces et données additionnelles; modifications à l'ouvrage de Nast (1987) (Homoptera). *Bulletin de la Société Entomologique de France* 106: 283–302.

Dietrich CH (2002) Evolution of Cicadomorpha (Insecta, Hemiptera). *Denisia*, 04: 155–170.

Dietrich CH (2005) Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). *Florida Entomologist* 88: 502–517.

Dimitrov T, Ruskov M (1927) Nasekomni I gubni vrediteli v naschite gori. *Gorski pregled* 13: 207–214.

Dlabola J (1981) *Metcalfa pruinosa* (Say, 1830), eine schadliche nordamerikanische Flatide als Erstfund in der Palaearktis (Insecta, Homoptera, Auchenorrhyncha). *Faunistische Abhandlungen (Dresden)* 8: 91–94.

Dolling WR (1991) *The Hemiptera*. London: Oxford University Press. 274 pp.

D'Urso V, Uliana M (2006) *Acanalonia conica* (Hemiptera, Fulgoromorpha, Acanaloniidae), a Nearctic species recently introduced in Europe. *Deutsche Entomologische Zeitschrift* 53: 103–107.

Duso C, Bressan A, Mazzon L, Girolami V (2005) First record of the grape leafhopper *Erythroneura vulnerata* Fitch (Hom., Cicadellidae) in Europe. *Journal of Applied Entomology* 129: 170–172.

Eichhorn O (1967) On methods of differentiating the species of the harmful white woolly aphids (Genus *Dreyfusia* CB. = *Adelges* AN.) on fir, and the consequences for forest protection. *Technical Bulletin of the Commonwealth Institute of Biological Control* 8: 53–82.

Eichhorn O (1991) On the generation cycle of *Dreyfusia nordmannianae* Eckst. (Hom., Adelgidae). *Journal of Applied Entomology* 112: 217–219.

Eichhorn O, Carter CI (1978) Investigation into conifer woolly aphids (Hemiptera: Adelgidae) in Japan, with the descriptions of two new species. *Zeitschrift fur Angewandte Entomologie* 86: 273–289.

Essl F, Rabitsch W (2002) Neobiota in Österreich. Umweltbundesamt, Wien, 432 pp.

Fauna Italia. *Checklist of the species of the italian fauna*. On-line version 2.0. www.faunaitalia.it/checklist/invertebrates/families/.

Forster B (2002) Auswirkungen eingewanderter oder eingeschleppter Insekten auf die Wald- und Parkbäume der Schweiz. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 75: 135–136.

Francke-Grossmann H (1937) Ökologie und Schadwirkung von *Dreyfusia prelli* Grossman. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 47: 497–516.

Francke-Grossmann H (1937) Zur Morphologie der Tannenlaus *Dreyfusia prelli* Grossmann und ihrer Galle auf *Picea orientalis* Lk. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 47: 465–482.

Garcia Garcia EJ, Garijo Alba C, Garcia Segura S (1992) Presencia de *Paraleyrodes* sp. pr. *citri* (Bondar, 1931) (Insecta: Homoptera: Aleyrodidae) en los cultivos de cítricos de la provincia de Málaga (sur de Espana) : aspectos biológicos y ecológicos de la plaga. *Boletin de Sanidad Vegetal* 18: 3–9.

Gederaas L., Salvesen I, Viken Å (Eds) (2007) *Økologiske risikovurderinger av fremmede arter [2007 Norwegian Black List – Ecological Risk Analysis of Alien Species].* Trondheim: Artsdatabanken. 152 p.pp.

Geiter O, Homma S, Kinzelbach R (2002) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltbundesamt 25: 1–173.

Ghauri MSK (1983) A case of long-distance dispersal of a leafhopper. In Knight WJ, Pant NC, Robertson TS, Wilson MR (Eds) Proccedings of the *1st International Workshop on leafhoppers and planthoppers of economic importance*. London: CIE. 249–255.

Glavendekić M, Mihajlović L, Petanović R (2007) Introduction and spread of invasive mites and insects in Serbia and Montenegro. In: Alford DV & Backhaus GF (Eds) *Abstracts of the Conference on Plant Protection and Plant Health in Europe, 'Introduction and spread of invasives species'.* Berlin, Germany: Humboldt University, June 2005

Gonzalez AD (2003) *Trioza erytreae* (Del Guercio, 1918): nueva plaga de los cítricos de Canarias. *Phytoma España*, 153: 112–120.

Guglielmino A (2005) Observations on the genus *Orientus* (Rhynchota, Cicadomorpha, Cicadellidae) and description of a new species*: O. amurensis* n.sp. from Russia (Amur Region and Maritime Territory) and China (Liaoning Province). *Marburger Entomologische Publikationen* 3, 99–110.

Günthart H, Mühlethaler R, Lauterer P (2004) Für die Schweiz neue Zikadenarten und Ergänzungen zu bereits bekannten Arten (Hemiptera, Auchenorrhyncha*). Mitteilungen der Entomologischen Gesellschaft Basel* 54, 150–160.

Havill NP, Foottit RG (2007) Biology and Evolution of Adelgidae. Annual *Review of Entomology* 52: 323–349.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw M, Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England. English Nature Research Reports N° 662*. Peterborough: English Nature, 81 pp.

Hodkinson ID (1999) Biocontrol of eucalyptus psyllids *Ctenarytaina eucalypti* by the Australian parasitoid *Psyllaephagus pilosus*: a review of current programmes and their success. *Biocontrol News and Information* 20 (4): 129–134.

Hodkinson ID (2007) A new introduced species of *Ctenarytaina* (Hemiptera, Psylloidea) damaging cultivated *Eucalyptus parvula* (=*parvifolia*) in Europe. *Deutsche Entomologische Zeitschrift* 54 (1): 27–33.

Hodkinson ID, Hollis D (1987) The legume-feeding psyllids (Homoptera) of the west Palaearctic Region. *Bulletin of the British Museum of natural History* 56: 1–86.

Hodkinson ID, White IM (1979a) *Homoptera Psylloidea. Handbooks for the Identification of British Insects. Vol II, Part 5 (a*). London: Royal Entomological Society. 98 pp.

Hodkinson ID, White IM (1979b) New psyllids from France with redescriptions of the type species of *Floria* Löw and *Amblyrhina* Löw (Homoptera Psylloidea). *Entomologica Scandinavica*, 10: 55–63.

Hollis D (1978) *Floria variegata* Löw (Homoptera: Psylloidea) on *Laburnum* in Britain. *Plant Patology* 27: 149.

Hollis D (1984) Afrotropical jumping plant lice of the family Triozidae (Homoptera: Psylloidea). *Bulletin of the British Museum (Natural History), Entomology series 49*: 1–102.

Hollis D, Broomfield PS (1989) *Ficus*-feeding psyllids (Homoptera), with special reference to the Homotomidae. *Bulletin of the British Museum (Natural History)*, *Entomology series* 58: 131–183.

Holman J, Pintera A (1977) Check-list of Czechoslovak Insects. *Acta Faunistica Entomologica Musei Nationalis Pragae* I: 101–116.

Holzinger WE, Jantscher E, Remane R (1996) Erstnachweise von Zikaden aus Österreich, mit Bemerkungen zu zwei weiteren Arten (Ins.: Homoptera, Auchenorrhyncha). *Linzer Biologische Beitraege* 28: 1149–1152.

Holzinger WE, Remane R (1994) Zikaden-Erstnachweise aus Österreich (Ins.: Homoptera, Auchenorrhyncha). *Mitteilungen des naturwissenschaftlichen Vereins für Steiermark* 124, 237–240.

Horvaáth G (1912) Az amerikai bivalykabócza Magyarországon. *Rovartani lapok. Budapest* 19: 145–147.

Iaccarino FM (1985) Nuovi generi e specie di Aleirodidi per la fauna italiana. *Bolletino del laboratorio di entomologia agraria "Filippo Silvestri"* 42: 135–141.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Délemont: CABI Bioscience Switzerland, 131–212.

King PD, Rilling G (1985) Variations in the galling reaction of grapevines: evidence of different Phylloxera biotypes and clonal reaction of Phylloxera. *Vitis*, 24: 32–42.

Klasa A, Soika G, Labanowski G (2003) *Massilieurodes chittendeni* (Laing, 1928) (Hemiptera: Aleyrodidae) – the whitefly species new to the Polish fauna. *Wiadomosci Entomologiczne* 22 (4): 197–200.

Kozár F, Bink-Moenen RM, Darvas B, Urfiné-Fogarsi E (1987) Új kártevö, a szamóca-molytetü (Trialeurodes packardi Morrill; Homoptera: Aleyrodidae) megjelenése Magyarországon. *Növényvédelem* 23: 351–354.

Kristensen NP (1991) Phylogeny of Extant Hexapods. In CSIRO (Ed) *The Insects of Australia*. Melbourne: Melbourne University Press, 125–140.

Laing F (1922) *Rhinocola eucalypti* Mask. In England. *Entomologist's Monthly Magazine* 58: 141.

Laing F (1928) Description of a white fly pest of rhododendrons. *Entomologist's Monthly Magazine* 64: 228–230.

Laudonia S (2006) Un nuovo psillide su eucalipto. *L'Informatore Agrario* : 89.

Lauterer P (1993) Notes on the bionomics and occurrence of some Psyllids (Homoptera, Psylloidea) in Czechoslovakia and the Balkan Peninsula. *Acta Musei Moraviae* 77: 147–156.

Lauterer P, Malenovský I (2002a) *Metcalfa pruinosa* (Say, 1830) introduced into the Czech Republic (Hemiptera, Flatidae). *Beiträge zur Zikadenkunde* 5: 10–13.

Lauterer P, Malenovský I (2002b) New distributional and biological data on European Psylloidea (Hemiptera, Sternorrhyncha), with special reference to the fauna of the Czech Republic and Slovakia. *Entomologica Basiliensia* 24: 161–177.

Louro V, Cabrita P (1989) Contribuição para o conhecimento da sua cultura em Portugal. Estudos e Informação Nº 126, 128. Lisboa: Direcção Geral das Florestas.

Maczey N, Wilson MR (2004) *Eupteryx decemnotata* Rey (Hemiptera, Cicadellidae) new to Britain. *British Journal of Entomology and Natural History* 17: 111–114.

Malausa JC, Sappei J, Franco E (1997) *Psylla acaciae-baileyanae*, un second psylle sur le mimosa dans le sud-est de la France. *Phytoma – La Défense des Végétaux*, 490: 57–59.

Malumphy C (2003) The status of *Bemisia afer* (Priesner & Hosny) in Britain (Homoptera: Aleyrodidae). *Entomologist's Gazette* 54: 191–196.

Malumphy C (2005) The Neotropical solanum whitefly, *Aleurotrachelus trachoides* (Back) (Hem., Aleyrodidae), intercepted in the U.K. on sweet potato leaves imported from Gambia. *Entomologist's Monthly Magazine* 141: 94.

Malumphy C, Halstead C (2003) *Cacopsylla fulguralis* (Kuwayama), an Asian jumping plant louse (hemiptera: psyllidae), causing damage to *Elaeagnus* in Britain. *British Journal of Entomology and Natural History* 16: 89–93.

Mani E, Baroffio C (1997) Biologische Bekämpfung der San-José-Schildlaus im Kanton Zug mit der Schlupfwespe *Encarsia perniciosi*. *Schweizer Zeitschrift für Obst- und Weinbau* 133, 392.

Mansilla J-P, Perez R, Del Estal P, Blond A (2004) Deteccion en Espana de *Ctenarytaina spatulata* Taylor sobre *Eucalyptus globulus* Labill. *Boletín de Sanidad vegetal, Plagas*, 30: 57–63.

Marchal P (1913) Contribution à l'étude de la biologie des Chermes. *Annales des Sciences Naturelles-Zoologie et Biologie Animale* 18: 153–385.

Martelli M (1960) Cenni su alcuni degli insetti più preoccupanti per le conifere a rapido incremento. Atti I Convegno nazionale Pioppo e Conifere a rapido incremento, Torino 23–25 aprile 1960, 3–9.

Martin JH (1996) Neotropical whiteflies of the subfamily Aleurodicinae established in the western Palaearctic (Homoptera: Aleyrodidae). *Journal of Natural History* 30: 1849–1859.

Martin JH (2000) The occurrence of *Dialeurodes citrifolii* and *Aleurochiton pseudoplatani* (Hemiptera: Aleyrodidae) in Lebanon – important new records in the Europe-Mediterranean Region. *Bulletin of Entomological Research* 90: 527–528.

Martin JH (2001) Description of an invasive new species of Neotropical aleurodicine whitefly (Hemiptera : Aleyrodidae) – a case of complete or partial misidentification ? *Bulletin of Entomological Research* 91: 101–107.

Martin JH, Aguiar AMF, Baufeld P (2001) *Crenidorsum aroidephagus* Martin & Aguiar sp. nov. (Sternorrhyncha : Aleyrodidae), a New World whitefly species now colonising cultivated Araceae in Europe, Macaronesia and the Pacific. *Zootaxa* 4: 1–8.

Martin JH, Hernandez-Suarez E, Carnero A (1997) An introduced new species of *Lecanoideus* (Homoptera : Aleyrodidae) established and causing economic impact on the Canary Islands. *Journal of Natural History* 31: 1261–1272.

Martin JH, Malumphy CP (1995) *Trioza vitreoradiata*, a New Zealand jumping plant louse (Homoptera : Psylloidea), causing damage to *Pittosporum* spp. in Britain. *Bulletin of Entomological Research* 85: 253–258.

Martin JH, Mound LA (2008) An annotated check list of the world's whiteflies (Hemiptera: Aleyrodidae). *Zootaxa* 1492: 1–84.

Martin JH, Aguiar A, Pita M (1996) Aleyrodidae of Madeira - Description of three new species and notes on a pan-mediterranean species of *Aleurotrachelus*. *Journal of Natural History* 30: 113–125.

Martin JH, Rapisarda C, Mifsud D (2000) The whiteflies (Hemiptera: Aleyrodidae) of Europe and the Mediterranean Basin. *Bulletin of Entomological Research* 90: 407–448.

Mercier L, Poisson R (1926) Un hémiptère de la famille des psyllines, parasite d'eucalyptus cultivés à Cherbourg. *Bulletin de la Société Linnéan de Normandie, Series 79*: 34–37.

Mifsud D (2010) Jumping plant-lice (Hemiptera : Psylloidea) of the Maltese Islands. *Bulletin of the Entomological Society of Malta* 3: in press.

Mifsud D, Watson GW (1999) Introduced sap-feeding insect pests of crop plants in the Maltese Islands. *The Central Mediterranean Naturalist* 3: 29–34.

Mound L (1961) A new genus and four new species of whitefly from ferns (Homoptera, Aleyrodidae). *Revue de Zoologie et de Botanique Africaine* 64: 127–132.

Mound LA, Halsey SH (1978) *Whitefly of the World*. Chichester, British Museum (Natural History): John Wiley & Sons. 340 pp.

Nickel H, Holzinger WE (2006) Rapid range expansion of Ligurian leafhopper, *Eupteryx decemnotata* Rey, 1891 (Hemiptera: Cicadellidae), a potential pest of garden and greenhouse herbs, in Europe. *Russian Entomological Journal* 15: 57–63.

Nielson MW (1985) Leafhopper systematics. In Nault LR, Rodriguez JG (Eds) *The leafhoppers and planthoppers*. New York: Wiley-Interscience. 11–39.

Nieto Nafria JM, Binazzi A (2005) *Super family Phylloxeroidea, Fauna Europaea*. http//www.faunaeur.org [accessed 07.03.2005].

O'Connor J-P, Dunne R, Whelton A (2004) *Trioza vitreoradiata* (Maskell) (Homoptera: Psylloidea), a New Zealand species new to Ireland. *Irish Naturalist' Journal* 27: 349–350.

O'Brien LB (2002) The Wild Wonderful World of Fulgoromorpha. *Denisia* 4: 83–102.

O'Brien L, Wilson SW (1985) Planthopper systematics and external morphology. In: Nault LR, Rodriguez JG (Eds) *The leafhoppers and planthoppers*. New York: Wiley-Interscience. 61–102.

OEPP/EPPO (1988) Data sheets on quarantine organisms No. 151, Citrus greening bacterium and its vectors *Diaphorina citri* & *Trioza erytreae*. *Bulletin OEPP/EPPO Bulletin* 18: 497–507.

Pašek V (1954) *Vošky našich lesných* drevín [Adelgids of our. Coniferous Trees]. Bratislava: Veda. 322 pp.

Pellizari G, Šimala M (2007) First record of *Aleuroclava guyavae* (Takahashi, 1932) (Hemiptera, Aleyrodidae) in Europe. *Bollettino di Zoologia Agraria e di Bachicoltura Serie II* 39(2): 91–95.

Pettey FW (1925) New South African psyllids. *South African Journal of Natural History* 5: 125–142.

Porcelli F (2008) First record of *Aleurocanthus spiniferus* (Homoptera: Aleyrodidae) in Apulia, Southern Italy. *Bulletin OEPP/EPPO Bulletin* 38: 518–520.

Priore R (1969) Il *Dialeurodes citri* (Ashmead) (Homoptera: Aleyrodidae) in Campania. *Bolletino del laboratorio di entomologia agraria "Filippo Silvestri*" 27: 287–316.

Rapisarda C (1985) Sulla presenza in Italia di *Acizzia acaciaebaileyanae* (Froggatt) (Homoptera, Psylloidea), nuovo parassita di Acacie ornamentali. *Informatore fitopatologico* 1985: 45–49.

Rapisarda C, Siscaro G, Leocata S, Asero C (1990) *Parabemisia myricae*, un nuovo aleirode degli agrumi in Italia. *Informatore fitopatologico* 40 (12): 25–30.

Redel D, Penzes B (2006) First occurrence of *Acizzia jamatonica* (Kuwayama, 1908) (Sternorrhyncha: Psyllidae: Acizziinae) in Hungary. *Novenyvedelem* 42: 153–157.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Roversi PF, Binazzi A. 1996. Life cycle of the Douglas-fir woolly aphid *Gilletteella coweni* (Gillette) in central Italy (Homoptera Adelgidae). *Redia* 79: 241–45.

Russell LM (1964) *Dialeurodes kirkaldyi* (Kotinsky), a whitefly new to the United States (Homoptera : Aleyrodidae). *The Florida Entomologist* 47: 1–4.

Schaefer HA (1949) Beiträge zur Kenntnis der Psylliden der Schweiz. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 22: 1–96.

Šefrová H, Laštùvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Seljak G (2002) Non-european Auchenorrhyncha (Hemiptera) and their Geographical distribution in Slovenia. *Acta Entomologica Slovenica* 10: 97–101.

Seljak G (2003) *Acizzia jamatonica* endangers Albizia trees. *Moj mali svet* 35: 20–21.

Seljak G (2004) Prokelisia marginata (Van Duzee, 1897) - nearkticna vrsta škržatkov, nova za Slovenijo in Evropo (Auchenorrhyncha: Delphacidae) *Prokelisia marginata* (Van Duzee, 1897) - a nearctic planthopper, new to Slovenia and Europe (Auchenorrhyncha: Delphacidae). *Acta Entomologica Slovenica* 12: 260–262.

Seljak G, Simala M, Stigter H (2004) Three new non-European psyllids (Hemiptera, Psyllidae) in Slovenia and Croatia. In: *Abstracts of the Third European Hemiptera Congress*, St Petersburg, November 2004: 66–67.

Sergel R (1987) On the occurrence and ecology of the Rhododendron-leafhopper *Graphocephala fennahi* Young 1977, in the western palaearctic region (Homoptera, Cicadellidae). *Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz* 60: 134–136.

Söderman G (2005) The eastern palaearctic leafhopper *Igutettix oculatus* (Lindberg, 1929) in Finland: morphology, phenology and feeding (Insecta, Hemitpera, Cicadellidae, Typhlocybinae). *Beiträge zur Zikadenkunde* 8: 1–4.

Stani A, Murraj Xh, Kapidani A (1974) *Entomologjia Bujqësore*-cited in Tomov et al (2009) (147).

Steffan AW (1972) Unterordnung Aphidina, Blattläuse. In: Schwenke W (Ed) (1972) *Die Forstschädlinge Europas, I. Band. Würmer, Schnecken, Spinnentier, Tausendfüssler und Hemimetabole Insecten.* Paul Parey, Hamburg and Berlin. pp. 162–386.

Stewart AJA (1993) *Placotettix taeniatifrons* (Kbm.) (Hem., Cicadellidae) in Bedfordshire. *Entomologist's Monthly Magazine* 129: 80.

Streito JC (2004) Découverte en France de *Crenidorsum aroidephagus* Martin & Aguiar, 2001, description de la femelle, caractères permettant de la différencier d'autres aleurodes d'intérêt agronomique (Hemiptera, Aleyrodidae). *Nouvelle Revue d'Entomologie* 21: 375–382.

Süss L, Salvodelli S (2003) Rinvenimento di *Cacopsylla fulguralis* (Kuwayama) (Homoptera Psyllidae) in Italia. *Bollettino di Zoologia agraria e di Bachicoltura* 35: 95–98.

Teodorescu I, Manole T, Iamandei M, Vadineanu A (2005) The main alien/invasive insect species in Romania. *Revue Roumaine de Biologie - Série de Biologie Animale* 51: 43–61

Tomov R, Trencheva K, Trenchev G, Cota E, Ramadhi A, Ivanov B, Naceski S, Papazova-Anakieva I, Kenis M (2009) *Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia*. Sofia-Moscow: Pensoft, publishers, 112 pp.

Trehan KN (1938) Two new species of Aleurodidae found on ferns in greenhouses in Britain (Hemiptera). *Proceedings of the Royal Entomological Society of London* (B) 7: 182–189.

Tremblay E (1981) *Entomologia applicata*, vol II (1), Napoli: Liguori Editore, 310pp.

Tremblay E (1988) Avversità delle colture di recente o temuta introduzione. Parassiti animali: Insetti. *Italia agricola* 115–128.

Tsitsipis JA, Katis N, Margaritopoulos J, Lykouressis D, Avgelis A, Gargalianou I, Zarpas K, Perdikis D, Papapanayotou A (2007) A contribution to the aphid fauna of Greece. *Bulletin of Insectology* 60: 31–38.

Valente C, Hodkinson I (2008) First record of the Red Gum Lerp Psyllid, *Glycaspis brimblecombei* Moore (Hem.: Psyllidae) in Europe. *Journal of Applied Entomology* 133: 315–317.

Valente C, Manta A, Vaz A (2004) First record of the Australian psyllid *Ctenarytaina spatulata* Taylor (Homoptera: Psyllidae) in Europe. *Journal of Applied Entomology* 128: 369–370.

Varty IW (1956). *Adelges Insects of Silver Firs*. Edinburgh: Her Majesty's Stationery Office. 75 pp.

Visnya A (1941) A gigantic species of Aleurodidae (Homoptera) from greenhouse-Orchideas. *Folia Entomologica Hungarica* 6: 4–15.

Wheeler Jr AG, Richard Hoebeke E (2009) *Acizzia jamatonica* (Kuwayama) (Hemiptera: Sternorrhyncha: Psyllidae): U.S. distribution of a recently detected Asian Psyllid. *Proceedings of the Entomological Society of Washington* 111 (2) : 505–514.

Wilson MR (1981) Identification of European *Iassus* species (Homoptera: Cicadellidae) with one species new to Britain. *Systematic Entomology* 6: 115–118.

Wilson MR, Claridge MF (1991)*Handbook for the identification of leafhoppers and planthoppers of rice*. Wallingford, Oxon: CAB International,142 pp.

Wilson SW, MacPherson JE (1981) Life histories of *Anormenis septentrionalis*, *Metcalfa pruinosa*, and *Ormenoides venusta* with descriptions of immature stages. *Annals of the Entomological Society of America* 74 (3): 299–311.

Wittenberg R (2005) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. CABI Bioscience Switzerland Centre report to the Swiss Agency for Environment, Forests and Landscape: 417pp.

Yoshizawa K, Saigusa T (2001) Phylogenetic analysis of paraneopteran orders (Insecta: Neoptera) based on forewing base structure, with comments on monophyly of Auchenorrhyncha (Hemiptera). *Systematic Entomology* 26: 1–13.

Zandigiacomo P, Bernardinelli I, Stergule F (2002) Psilla dell' albizzia: prima segnalazione per l'Italia nord-orientale. *Notizia/ERSA* 2002: 18–20

Table 9.4.1. List and main characteristics of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha species alien *to* Europe. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Only selected references are given

Suborder *Superfamily* **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sternorrhyncha								
Aleyrodidae (*Aleyrodinae*)								
Acaudaleyrodes rachipora (Singh, 1931)	A	Phyto-phagous	Oriental Region	2000, ES-CAN	ES-CAN	I2	Polyphagous	Martin et al. (2000)
Aleurocanthus spiniferus (Quaintance, 1903)	A	Phyto-phagous	Oriental Region	2008, IT	IT	I	Polyphagous; occasionally a pest on *Annona* and *Citrus*	Porcelli (2008)
Aleuroclava aucubae (Kuwana, 1911)	A	Phyto-phagous	Oriental Region	2007, IT	IT	I2, J100	*Psidium*, *Cinnamomum*, *Citrus*, *Ficus*, *Pittosporum*, *Prunus*, *Photinia*	Pellizari and Šimala (2007)
Aleuroplatus perseaphagus Martin et al., 1996	A	Phyto-phagous	Neotropical Region	1991, ES-MAD	PT-MAD	I2	Avocado mainly	Martin et al. (1996)
Aleuropteridis filicicola (Newstead, 1911)	A	Phyto-phagous	Africa	1961, GB	GB	J100	*Pteris togoensis, Cyclosorus dentatus, Oleandra articulata*	Mound (1961)[1]
Aleurothrixus floccosus Maskell, 1895	A	Phyto-phagous	Neotropical Region	1968, ES-CAN; 1969, FR	AL, ES-CAN, FR, FR-COR, GR, IL, IT, IT-SAR, IT-SIC, MT, PT, GB	I2, J100	Polyphagous; a preference for *Citrus* where established	Martin et al. (2000)
Aleurotrachelus atratus Hempel, 1922	A	Phyto-phagous	Neotropical Region	2000, ES-CAN	ES-CAN, FR	I2, J100	*Cocus* spp.	Borowiec et al. (2010)

[1] Mound (Mound 1961) redescribed this species under the name of *A. douglasi* from material collected on ferns in Kew Gardens, UK.

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aleurotrachelus trachoides (Back, 1912)	A	Phyto-phagous	Neotropical Region	2005, GB	GB	? J100	Sweet potato leaves	Malumphy (2005)
Aleurotulus nephrolepidis (Quaintance, 1900)	A	Phyto-phagous	C & S America	1938, GB	ES, ES-CAN, GB, HU	J100	Ferns	Trehan (1938)
Bemisia tabaci (Gennadius, 1889)	A	Phyto-phagous	? Asia	?	AL, AT, BE, BG, CH, CY, CZ, DE, ES, ES-BAL, ES-CAN, FR-COR, FR, DE, GR-CRE, GR, HU, HR, IL, IT, IT-SAR, IT-SIC, MT, NL, NO, PL, PT, RO, RU	I1, J100	Polyphagous crops & greenhouses	Martin et al. (2000)
Crenidorsum aroidephagus Martin & Aguiar, 2001	A	Phyto-phagous	C & S America	1998, PT-MAD	DE, FR, PT-MAD	J100, I2	Araceae	Martin et al. (2001), Streito (2004)
Dialeurodes citri (Ashmead, 1885)	A	Phyto-phagous	Oriental Region	1945 ?	AL, FR, FR-COR, IL, IT, IT-SAR, IT-SIC, MT, SI	I2	Polyphagous; a preference for *Citrus* where established	Priore (1969)
Dialeurodes kirkaldy (Kotinsky, 1907)	? A	Phyto-phagous	? New World	?	CY, IL, PT	I2	Polyphagous; a preference for *Jasminum* and *Morinda citrifolia*	Russell (1964)
Filicaleyrodes williamsi (Trehan, 1938)	A	Phyto-phagous	? Tropical Africa	1938, GB	GB, HU	J100	Ferns	Trehan (1938)
Massilieurodes chittendeni (Laing, 1928)	A	Phyto-phagous	Northern Asia	1928, GB	BE, CH, CZ, DE, DK, FI, FR, GB, IT, NL, PL, SE	I2	Rhododendron	Laing (1928)

Suborder *Superfamily* Family (*Subfamily*)	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Parabemisia myricae (Kuwana, 1927)	A	Phyto-phagous	Asia	mid 1980's	CY, ES, ES-CAN, FR, FR-COR, GR-CRE, IL, IT, IT-SAR, IT-SIC, PT	I2	Polyphagous; a preference for citrus and avocados (in Europe)	Rapisarda et al. (1990)
Pealius azaleae (Baker & Moles, 1920)	A	Phyto-phagous	Eastern Asia	1920, BE	BE, GB, IT, NL	I2, J100	Rhododendron	Martin et al. (2000)
Singiella citrifolii (Morgan, 1893)	? A	Phyto-phagous	? New World	1998, PT-MAD	PT-MAD	I2	*Citrus* mainly	Martin (2000)
Trialeurodes packardi (Morrill, 1903)	A	Phyto-phagous	Nearctic Region	1987, HU	HU	I2	Strawberries (in Europe)	Kozár et al. (1987)
Trialeurodes vaporariorum (Westwood, 1856)	A	Phyto-phagous	North America	1856, GB	AL, AT, BG, CH, CZ, DE, DK, EE, FR, HU, IT, IT-SAR, IT-SIC, LT, MT, PT, RO, RS, SI	I2, J100	Polyphagous	Martin et al. (2000)
Aleyrodidae (*Aleurodicinae*)								
Aleurodicus destructor Mackie, 1912	A	Phyto-phagous	Neotropical Region	?, GB	GB	J100	Polyphagous	Martin (1996)
Aleurodicus dispersus Russell, 1965	A	Phyto-phagous	Neotropical Region	1962, ES-CAN	ES, ES-CAN, PT-MAD	I2	Polyphagous; a preference for *Citrus* where introduced	Martin (1996)
Ceraleurodicus varus (Bondar, 1928)	A	Phyto-phagous	Neotropical Region	1939	HU	J100	Orchids	Visnya (1941)
Lecanoideus floccissimus Martin et al., 1997	A	Phyto-phagous	Neotropical Region	1994, ES-CAN	ES-CAN	I2	Polyphagous	Martin et al. (1997)
Paraleyrodes bondari Peracchi, 1971	A	Phyto-phagous	Neotropical Region	1995, PT-MAD	PT-MAD	I2	Polypagous, also on *Citrus* spp.	Martin (1996)

Suborder *Superfamily* Family (*Subfamily*)	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Paraleyrodes citricolus Costa Lima, 1928	A	Phyto-phagous	Neotropical Region	1994, PT-MAD	PT-MAD	I2	*Citrus* spp., *Persea Americana*	Martin (1996)
Paraleyrodes minei Iccarino, 1990	A	Phyto-phagous	Neotropical Region	1990, ES	ES	I2	Mainly on *Citrus* spp.	Garcia Garcia et al. (1992)
Psylloidea								
Psyllidae								
Acizzia acaciaebaileyanae (Froggatt, 1901)	A	Phyto-phagous	Australia	1981, FR	FR, IT, IT-SIC, SI	I2, F	*Acacia baileyana*	Malausa et al. (1997), Rapisarda (1985),Stoch (2003), Seljak et al. (2004)
Acizzia hollisi Burckhardt, 1981	A	Phyto-phagous	Africa	1987, IT	IT (Lampedusa)	I2, F	*Acacia raddiana*, cultivated *Acacia* spp.	Conci and Tamanini (1989)
Acizzia jamatonica (Kuwayama, 1908)	A	Phyto-phagous	Western Asia	2002, IT	CH, FR, FR-COR, HR, HU, IT	I2, F	*Albizzia julibrissima*	Chapin and Cocquempot (2005), Seljak et al. (2004), Seljak (2003), Wittenberg (2005), Rédei and Pénzes (2006), Zandigiacomo
Acizzia uncatoides (Ferris & Klyver, 1932)	A	Phyto-phagous	Australia	1974, FR	ES-CAN, FR, IL, IT, IT-SIC, ME, MT, PT	I2, F	*Acacia floribunda*	Hodkinson and Hollis (1987), Lauterer (1993), Malausa et al. (1997), Stoch (2003), Seljak et al. (2004)
Blastopsylla occidentalis Taylor, 1985	A	Phyto-phagous	Australia	2006, IT	IT	I2	*Eucalyptus* spp.	Laudonia (2006)
Cacopsylla fulguralis (Kuwayama, 1908)	A	Phyto-phagous	Western Asia	1999, FR	BE, CH, ES, FR, GB, IT	I2	*Elaeagnus* x *ebbingei*	Baugnée (2003), Cocquempot (2008), Cocquempot and Germain (2000), Malumphy and Halstead (2003), Süss and Salvodelli (2003), Wittenberg (2005)
Cacopsylla pulchella (Löw, 1877)	A	Phyto-phagous	Eastern Medi-terranean	1964, FR	FR, GB, CH, IT, IT-SIC	I2	*Cercis siliquastrum*	Klimaszewski (1973), Hodkinson and White (1979a), Hodkinson and White (1979b), Burckhardt (1983), Stoch (2003)

Suborder *Superfamily* Family (*Subfamily*)	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Ctenarytaina eucalypti (Maskell, 1890)	A	Phyto-phagous	Australia	1922, GB	CH, DE, ES, FR, GB, IE, IT, PT	I2, G5	*Eucalyptus* spp.	Burckhardt (1998), Cavalcaselle (1982), Hodkinson (1999), Hodkinson and White (1979a), Laing (1922), Mercier and Poisson (1926), Nogueira (1971), Rupérez and Cadahia (1973), Wittenberg (2005)
Ctenarytaina peregrina Hodkinson, 2007	A	Phyto-phagous	Australia	2006, GB	FR, GB, IT	I2	*Eucalyptus parvula*	Hodkinson (2007)
Ctenarytaina spatulata Taylor, 1967	A	Phyto-phagous	Australia	2002, PT	ES, FR, IT, PT	I2, G5	*Eucalyptus* spp.	Costanzi et al. (2003), Mansilla et al. (2004), Valente et al. (2004)
Glycaspis brimblecombei (Moore, 1964)	A	Phyto-phagous	Australia	2008, ES, PT	ES, PT	I2, G5	*Eucalyptus* spp.	Valente and Hodkinson (2008)
Triozidae								
Trioza erythreae (Del Gercio, 1918)	A	Phyto-phagous	Western Africa	1994, MAD	ES-CAN, PT-MAD	I2	*Citrus* trees	Borges et al. (2008), Gonzalez (2003)
Trioza neglecta (Loginova, 1978)	A	Phyto-phagous	South-western and Central Asia	1982, CZ	AT, BG, CZ, HU, SK, RO, YU	I2	*Elaeagnus angustifolia*	Lauterer (1993), Lauterer and Malenovský (2002b)
Trioza vitreoradiata (Maskell, 1879)	A	Phyto-phagous	New Zealand	1993, GB	FR, GB, IE	I2	*Pittosporum* spp.	Cocquempot (2008), Malumphy et al. (1994), O'Connor et al. (2004)
Phylloxeroidea								
Adelgidae								
Adelges (*Gilletteella*) *cooleyi* (Gillette, 1907)	A	phyto-phagous	Western North America	1913, GB	AT, CH, CZ, DE, DK, FR, GB, IE, IT, NL, PL, PT, RO, RS, SE, SK, UA	G3, I2	*Picea (I), Pseudotsuga (II)*	Chrystal (1922), Covassi and Binazzi (1981), Essl and Rabitsch (2002), Forster (2002), Glavendekić et al. (2007), Nieto Nafria and Binazzi (2005), Pašek (1954)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Adelges (*Gilletteella*) *coweni* (Gillette, 1907)	A	phyto-phagous	North America	>1900, IT	AT, IT, PT	G3, I2	*Pseudotsuga* (anholocyclic)	Carter (1983), Essl and Rabitsch (2002), Louro and Cabrita (1989), Nieto Nafria and Binazzi (2005), Roversi and Binazzi (1996), Steffan (1972)
Adelges (*Dreyfusia*) *merkeri* Eichhorn 1957	A	phyto-phagous	Asia Minor	>1900, IT	AT, CZ, DE, IT, SE	G3	*Picea (I), Abies (II)*	Binazzi and Covassi (1988), Fauna Italia, Nieto Nafria and Binazzi (2005)
Adelges (*Dreyfusia*) *nordmannianae* (Eckstein, 1890)	A	phyto-phagous	Caucasus Mountains	1840, DE	AT, BG, CH, CZ, DE, DK, EE, FR, GB, HU, IE, IT, LV, NL, PL, PT, RS, SE, SI, SK, UA	G3	*Picea (I), Abies (II)*	Binazzi and Covassi (1988), Dimitrov and Ruskov (1927), Eichhorn (1967), Eichhorn (1991), Essl and Rabitsch (2002), Fauna Italia, Glavendekić et al. (2007), Marchal (1913), Nieto Nafria and Binazzi (2005), Pašek (1954), Varty (1956)
Adelges (*Dreyfusia*) *prelli* Grosmann, 1935	A	phyto-phagous	Caucasus mountains	<1900, IT	AT, CH, CZ, DE, IT, SE, SK	G3	*Picea, Picea orientalis (I), Abies (II)*	Binazzi and Covassi (1988), Eichhorn (1967), Francke-Grossmann (1937a), Francke-Grossmann (1937b), Nieto Nafria and Binazzi (2005), Šefrová and Laštùvka (2005)
Adelges (*Cholodkovskya*) *viridula* (Cholodkowsky, 1911)	A	phyto-phagous	North-western Russia	?, CZ	CZ, DK, ES, GB, SE, SI, SK, YU	G3	*Larix* (anholocyclic)	Nieto Nafria and Binazzi (2005), Šefrová and Laštùvka (2005), Steffan (1972)
Pineus (*Pineus*) *orientalis* (Dreyfuss, 1889)	A	phyto-phagous	Caucasus mountains	1913, CZ	CZ, DE, DK, GB, IT, NL, SK, UA	G3, I2	*Picea orientalis (I), Pinus (II)*	Bayer (1914), Covassi and Binazzi (1981), Hill et al. (2005), Marchal (1913), Nieto Nafria and Binazzi (2005)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pineus (*Pineus*) *similis* (Gillette 1907)	A	phyto-phagous	North America	1971, GB	GB	G3	*Picea sitchensis* (anholocyclic)	Carter (1975), Carter (1975)
Pineus (*Eopineus*) *strobi* (Hartig, 1837)	A	phyto-phagous	Eastern North America	1900, CZ	AT, BG, CH, CZ, DE, DK, GB, IT, LV, NL, PL, RO, RS, SE, SK, UA	G3, I2	*Pinus strobus* (anholocyclic)	Bayer (1920), Essl and Rabitsch (2002), Glavendekić et al. (2007), Martelli (1960), Nieto Nafria and Binazzi (2005), Steffan (1972)
Phylloxeridae								
Moritziella corticalis (Kaltenbach, 1867)	C	phyto-phagous	Cryptogenic	1970, GB	AT, DE, GB, IT, MD, NL, UA	G,I2	*Quercus petreae*	Barson and Carter (1972), Fauna Italia, Nieto Nafria and Binazzi (2005)
Viteus vitifoliae (Fitch, 1855)	A	phyto-phagous	North America	1860, FR	AL, AT, BG, CH, CZ, DE, ES, FR, GR, HR, HU, IE, IL, IT, IT-SAR, IT-SIC, MD, MT, PT, PT-MAD, RO, RS, SI, UA	I	*Vitis*	Aloi (1898), Anonymous (1894), Baudyš (1935), Essl and Rabitsch (2002), Fauna Italia, Glavendekić et al. (2007), Nieto Nafria and Binazzi (2005), Roll et al. (2007), Stani et al. (1974), Teodorescu et al. (2005), Tremblay (1981), Tsitsipis et al. (2007), Wittenberg (2005)
Auchenorrhyncha								
Cicadomorpha								
Cicadellidae								
Erythroneura vulnerata (Fitch, 1851)	A	Phyto-phagous	North America	2004, IT	IT	I	*Vitis*	Duso et al. (2005)
Graphocephala fennahi Young, 1977	A	Phyto-phagous	North America	1933, GB	AT, BE, CH, CZ, DE, DK, FR, GB, IT, NL, SI	FB, G, I2, X11, F	*Rhododendron*	Sergel (1987)
Igutettix oculatus (Lindberg, 1929)	A	Phyto-phagous	East Asia	1984, RU	FI, RU	I2	*Syringa*	Söderman (2005)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Japananus hyalinus (Osbom, 1900)	A	Phyto-phagous	East Asia	1942, AT	AT, BG, CH, CZ, DE, ES, FR, HU, IT, ME, RO, RS, RU, SI, SK	I2, G1	*Acer*	Seljak (2002)
Kyboasca maligna (Walsh, 1862)	A	Phyto-phagous	North America	1997, FR	BE, FR	I	*Pyrus, Crataegus*	Della Giustina and Remane (2001)
Macropsis elaeagni Emeljanov, 1964	A	Phyto-phagous	Asia (Caucasus)	1982, CZ	AT, BG, CZ, DE, HU, RO, SI, UA	I2, G5	*Elaeagnus*	Holzinger and Remane (1994)
Orientus ishidae (Matsumura, 1902)	A	Phyto-phagous	East Asia	2002, CH	AT, CH, CZ, DE, FR, IT, SI	I2	*Salix, Betula,* fruit tress	Guglielmino (2005), Günthart et al. (2004)
Scaphoideus titanus Ball, 1932	A	Phyto-phagous	North America	1958, FR	AL, AT, BG, CH, ES, FR, HU, IT, PT, RS, SI	I1	*Vitis*	Arzone et al. (1987)
Membracidae								
Stictocephala bisonia Kopp & Yonke, 1977	A	Phyto-phagous	North America	< 1912, HU	AL, AT, BA, BE, BG, CH, CZ, DE, ES, FR, HR, HU, IT, IT-SAR, IT-SIC, MD, ME, MK, NL, PL, RO, RS, SI, SK, UA	I2	Polyphagous	Arzone et al. (1987), Seljak (2002)
Fulgoromorpha								
Acanaloniidae								
Acanalonia conica (Say, 1830)	A	Phyto-phagous	North America	2003, IT	IT	I, J	Polyphagous	D'Urso and Uliana (2006)
Delphacidae								
Prokelisia marginata (Van Duzee,1897)	A	Phyto-phagous	North America	2003, SI	ES, FR, GB, PT, SI	D6	*Spartina maritima*	Seljak (2004)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Flatidae								
Metcalfa pruinosa (Say, 1830)	A	Phyto-phagous	North America	1970, FR	AL, AT, BA, BG, CH, CZ, FR, FR-COR, GR, HR, HU, IT, IT-SAR, IT-SIC, RS, SI, SK	I	Polyphagous	Dlabola (1981), Lauterer and Malenovský (2002a)

Glossary of the technical terms used in the book (marked by *)

Alatae: winged forms in aphids, adelgids, and other hemipterans.

Ampelophagous: related to the grapevine.

Anholocyclic: in cyclically parthenogenetic organisms, life cycles that do not include a sexual generation (e.g., in adelgids).

Archegonia: female multicellular egg-producing organ occurring in mosses, ferns, and most gymnosperms.

Archeozooan: an alien animal introduced to Europe since the beginning of the Neolithic agriculture but before the discovery of America by Columbus in 1492 (Daisie 2009).

Arrhenotoky: a common form of sex-determination in Hymenoptera and some other invertebrates, in which progeny are produced by mated or unmated females, but fertilized eggs produce diploid female offspring, whereas unfertilized eggs produce haploid male offspring by parthenogenesis (only the females are biparental).

Carina (sg.), **Carinae (pl.):** a ridgelike structure (e.g. antennal longitudinal ridge).

Cercus (sg.), **Cerci (pl.):** paired sensory structures at the posterior end of some arthropods.

Clava: apically differentiated region (sometimes club-like) of the antennal flagellum.

Dealate: having lost its wings; used for ants and other insects that shed their wings after the mating flight.

Declivity: posterior portion of the elytra that descends to its apex.

Domestic: living in human habitats.

Endofurca: the internal skeleton of the meso-and metathorax, that provides important muscle insertion points. In some thrips, the metasternal endofurca provides the insertion for powerful muscles that are associated with a remarkable jumping ability of adults.

Endophytic (adj): living inside a plant.

Endopterygote: insect that undergoes complete metamorphosis, with the larval and adult stages differing considerably in their structure and behaviour.

Epigyne: the external female sex organ in arachnids.

Exarate: for a pupa, having the appendages free and not attached to the body (as opposed to Obtect).

Exopterygote: insect that undergoes incomplete metamorphosis. The young (called nymphs) resemble the adults but lack wings; these develop gradually and externally in a series of stages or instars until the final moult produces the adult insect. There is no pupal stage.

Flagellum: the part of the antenna beyond the pedicel, which is differentiated into three regions, the anellus, funicle and clava.

Frass: waste material produced by feeding insects, including excrement and partially chewed vegetation.

Funicle: region of the antennal flagellum between the anellus and clava.

Gallicolae: leaf gall making forms; e.g., in phylloxerans.

Gnathosoma: anterior body region in mites.

Halobiont: an organism that lives in a salty environment.

Hemimetabolous: the type of insect development in which there is incomplete or partial metamorphosis, typically with successive immature stages increasingly resembling the adult; see Exopterygote.

Holocyclic: in cyclically parthenogenetic organisms, life cycles that include a sexual generation (e.g., in adelgids).

Holoptic: as in flies, with compound eyes meeting along the dorsal midline of the head.

Hyperparasitoid: a parasitoid living on or in another parasitoid.

Idiobiont parasitoid: a parasitoid which prevents further development of the host after initial parasitization.

Idiosoma: abdomen of mites and ticks.

Kleptoparasitoid: a parasitoid which preferentially attacks a host that is already parasitized by another species.

Koinobiont parasitoid: a parasitoid which allows the host to continue its development and often does not kill or consume the host until the host is about to either pupate or become an adult.

Ligula: the apical lobe of the labium.

Megagametophyte: female haploid, gamete-producing tissue in conifers.

Mesothorax: the second, and usually the largest, of the three primary subdivisions of the thorax in insects.

Mesonotum: the dorsal part of the mesothorax.

Metathorax: the third of the three primary subdivisions of the thorax in insects.

Metanotum: the dorsal part of the metathorax.

Moniliform: bead-like (as in antennae).

Mycangium (sg.), **mycangia (pl.):** usually complex structures on the insect body that are adapted for the transport of symbiotic fungi, usually spores.

Neozooan: an alien animal introduced to Europe after the discovery of America by Columbus in 1492 (Daisie 2009) .

Notaulix (sg.), **Notaulices (pl.):** one of a pair of grooves on the mesoscutum, from the front margin to one side of the midline and extending backward; divides the mesoscutum into three parts.

Obtect: for a pupa, having the legs and other appendages fused to the body.

Oniscomorph: the state as in 'pill' millipedes of being able to roll up in a ball.

Opisthosoma: posterior part of the body in spiders and mites.

Paranota: lateral wings.

Parthenogenesis, parthenogenetic (adj.): the production of offspring from unfertilized eggs. Special cases of this state are arrhenotoky, pseudo-arrhenotoky, and thelytoky.

Phytoplasma: prokaryotes that are characterized by the lack of a cell wall, associated with plant diseases.

Phytotelmatum (sg.), **Phytotelmata (pl.):** a small, water-filled cavity in a tree or any similar environment.

Podosoma: anterior section of idiosoma in ticks; serving as connecting area for the four pairs of legs.

Porrect: extended, especially forward; e.g., porrect mandibles.

Proctiger: the reduced terminal segment of the abdomen which contains the anus.

Prognathous: with the head more or less in the same horizontal plane as the body, and the mouthparts directed anteriorly.

Pronotum: the dorsal part of the prothorax.

Propodeum: the first abdominal segment.

Prosoma: anterior part of the body in spiders and mites; also called cephalothorax.

Prothorax: The first of the three primary subdivisions of the thorax in insects.

Pseudo-arrhenotoky: A form of sex-determination (especially in some scale insects and mites) in which males and females arise from fertilized eggs and are diploid. However, males become haploid by inactivation of the paternal genomic complement.

Puparium (sg.), **puparia (pl.):** the enclosing case of a pupa.

Reticulate: net-like, anastomosing.

Rostrum: beak-shaped projection on the head; e.g., in weevils.

Scutellum: the middle region of the mesonotum or metanotum, behind the scutum.

Scutum: the anterior part of the mesonotum or metanotum.

Secondary pest: a pest that attacks only weakened plants.

Sensorium: sensory structure present on antenna.

Siphunculi, **siphuncular (adj.):** pair of protruding horn-shaped dorsal tubes in aphids which secrete a waxy fluid.

Spatula sternalis: median cuticular sclerite, often bilobed, on the ventral side of the prothoracic segment of the last instars of some midge larvae; plays a role in larval locomotion.

Stigma: conspicuous, usually melanised area at the apex of a vein of the forewing, generally at the leading wing edge.

Sulcate: having narrow, deep furrows or grooves.

Synanthropic: ecologically associated with humans.

Tegula: Small, typically oval sclerite that covers the region of the mesothorax where the forewing and thorax articulate.

Thelitoky: A form of sex-determination (especially in Hymenoptera Symphyta and Cynipidae) in which only diploid female progeny are produced by parthenogenesis.

Termen: distalmost edge of wing.

Transhumance: in the case of hives, moving to new environments, according to the change in season.

Xylophagous (adj.): feeding on wood.

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RESEARCH ARTICLE

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Diptera
Chapter 10

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Abstract
Of the 19,400 native species and 125 families forming the European diptera fauna, 98 species (less than 0.5%) in 22 families are alien *to* Europe. These aliens constitute 66 species (18 families) of the suborder Brachycera and 32 species (4 families) of the suborder Nematocera. By family in this category, there are 23 Cecidomyiidae species, 18 Drosophilidae, nine Phoridae, eight Tachinidae and seven Culicidae. Another 32 fly species belonging to five families are considered to be alien *in* Europe. These invasives native to other European countries are composed of 14 species of Cecidomyiidae, seven Syrphidae, five Culicidae and three species each of Anthomyiidae and Tephritidae. The date of the first record in Europe is known for 84 alien species. Arrivals of alien species of Diptera have accelerated rapidly since the second half of the 20th century. North America appears to be the dominant contributor of the alien flies. The majority of alien Diptera were introduced into or within Europe unintentionally, with only three predators released intentionally for biological control. Alien Diptera are predominantly phytophagous (35.6%), while a lesser portion are zoophagous (28.6%) or detrivorous /mycetophagous (29.6%). Ecological impacts on native fauna and flora have not been documented for any of the alien species established in Europe. However, 14 alien species have economic impacts on crops.

Keywords
alien, Europe, Diptera

10.1 Introduction

Diptera is one of the largest insect orders, with a worldwide distribution. The order includes 172 to 179 families (depending on authors) with about 132,000 species described which probably underestimates the actual fauna by at least a half. About 19,400 native species and 125 families have been recorded in Europe (Fauna Europaea). The alien entomofauna is comparatively very limited with only 98 species observed to date, i.e. less than 0.5% of the total dipteran fauna in Europe.

Commonly called true flies, mosquitoes, midges, deer- and horseflies and houseflies feature among the most familiar Diptera. Flies are not only abundant in popular perception but also have particular veterinary and medical importance for vectoring diseases and as pests of agriculture, forestry and husbandry. However, some species are useful to man as parasitoids and predators of insect pests and as plant pollinators. Generally, adults are minute to small, soft-bodied insects with a highly mobile head, large compound eyes, antennae of variable size and structure, and sucking mouthparts. They have only one pair of functional wings, the second pair being changed into small head-like bodies called halteres. Legs are usually long, with five-segmented tarsi. Adults are usually very active and are found in all major habitats. They are often associated with flowers and with decaying organic matter, but females of some groups are blood-sucking. Larvae are eruciform and legless in most species. They develop mainly in moist or wet habitats such as soil, mud, decaying organic matter, and in plant or animal tissues. Only a small proportion of larvae is truly aquatic. The majority are liquid-feeders or microphagous.

10.2. Taxonomy of the Diptera species alien *to* Europe

The 98 species of Diptera alien *to* Europe belong to 22 different families (Table 10.1), which all have native representatives. A larger number of aliens belong to the suborder Brachycera (66 species and 18 families) than to the suborder Nematocera (32 species and 4 families). However, this apparently large diversity is confusing. More than 40% of the alien species are either midges (Cecidomyiidae- 23 species) or fruit flies and their relatives (Drosophilidae- 18 species). The other 20 families show less than 10 species each (Figure 10.1). The arrival of these alien species has largely modified the composition of some families such as Braulidae and Drosophilidae where at present aliens respectively account for 33.3% and 14.8% of the total fauna observed in Europe. However, the native entomofauna includes 103 additional families for which no alien species has yet been recorded in Europe, especially for some ecologically and economically- important groups such as Chironomidae, Syrphidae, Asilidae, Tipulidae and Anthomyiidae. The alien dipterans belong to the following families:

Suborder Brachycera

Agromyzidae. All species in the family are phytophagous, including a number of serious pests of cultivated plants. Larvae live in plant tissues, usually forming characteristic galleries as mines. Most larvae live in the parenchyma of leaves, or mine stems, few attack fruits and seeds. The majority of the species are monophagous, some of them are widely polyphagous, attacking different plants of several families. To date, only five alien species have been observed in Europe relatively to 903 recorded native species (Fauna Europaea). However, the alien fauna includes three species of *Liriomyza* (*L. chinensis, L. huidobrensis* - see factsheet 14.23*,* and *L. trifolii*) which are highly damaging to vegetable crops (Arzone 1979, Martinez 1982, Trouvé et al. 1991).

Braulidae. Larvae live as commensals within cells of honey-bee nests (*Apis* species). They feed on pollen, honey and organic debris. Adults are "food-parasites" of adult bees, attaching themselves to the body of the queen or rarely to a worker. They feed on liquids from the mouth of the bees. There is only one genus present in Europe, *Braula,* which includes one alien species, *B. schmitzi* (Dobson 1999), and two native species.

*Calliphorida*e. This is a key family for human health. Adults are potential vectors of bacteria, viruses, protozoaires and helminthes because they actively search for and sit on feces, fresh and cooked meat, fish, dairy products, and wounds. Larvae are parasitoids or predators of living snails, or feed on blood of nestling birds. A few species are obligate producers of *myiasis* in various animals. Only one alien species, *Chrysomya albiceps* (Mercier 1927), has been observed in Europe compared to 112 native species.

Canacidae (=Tethinidae). Most species are strictly associated with salty habitats (*halobionts*), e.g. coastal salt marshes, seashore wrack, sandy beaches, shores of inland salt lakes, alkaline springs etc, and only a few species are also known from habitats that are apparently without increased salinity (forests, meadows, deserts). Some species have been reared from deposits of seaweed. There is only one alien species, *Pelomyia occidentalis* (Irwin et al. 2001), compared to a total of 39 native species.

Ceratopogonidae. Biting adults of this family are potential vectors of major animal diseases. In particular, *Culicoides* species transmit bluetongue orbivirus between ruminant hosts. A species of Afro-Asian origin, *C. imicola* Kieffer, has been considered as the main agent of the recent outbreaks of bluetongue disease in Europe although some native species could also be involved (e.g., *C. pulicarius* L. and *C. newsteadi* Austen complexes (Purse et al. 2007)). However, it seems that the most likely mode of incursion of *C. imicola* in Europe was via passive transport on the wind as aerial plankton" (Mellor et al. 2008, Purse et al. 2007). Thus, this species was not considered in this chapter.

Dolichopodidae. Adults and larvae of most species are predaceous and feed on soft-bodied invertebrates. They occupy all terrestrial habitats from coastal beaches to high elevations, but they generally prefer humid areas. Larvae are mostly found in moist soils or in the litter layer while a few others depend on sap runs and tree rot holes for their development. There is only one alien species, *Micropygus vagans* (Chandler 2004), in comparison to 790 native species in Europe.

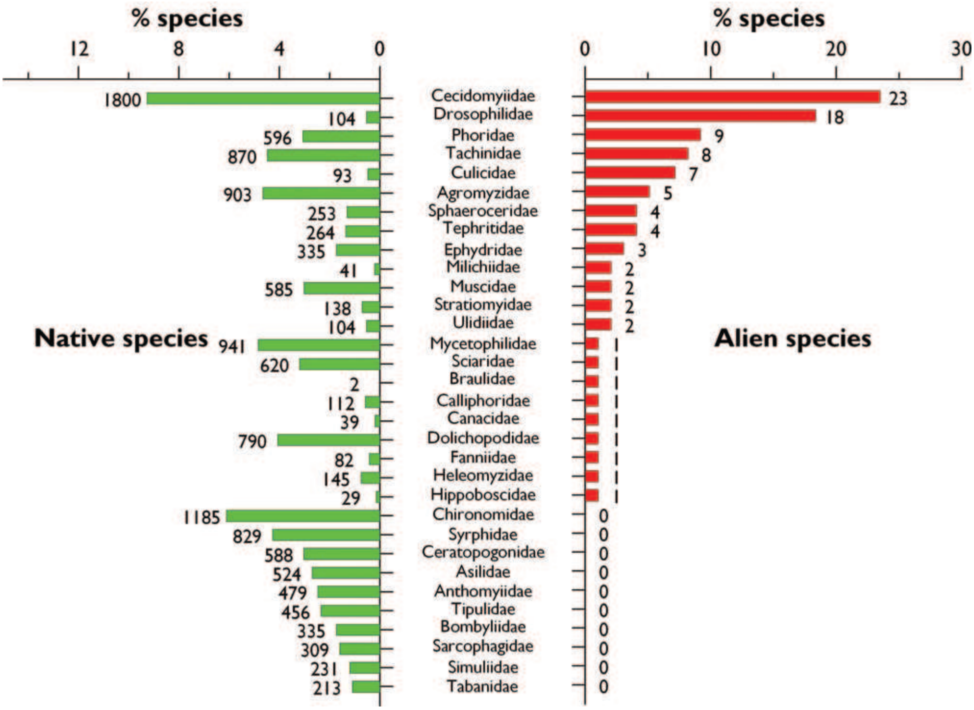

Figure 10.1. Relative importance of the families of Diptera in the alien and native entomofauna in Europe. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. Only the most important families of native species (> 50 spp.) have been considered. The number over each bar indicates the number of species observed per family.

Drosophilidae. Species in this family show very diverse biological habits. The larvae of most species develop in fermenting substrates, but some mine living plants. Some species are used as important laboratory animals. Drosophilids occur in all terrestrial habitats, from lowlands up to alpine meadows. They may be found near the habitats of their insect hosts or preys (mealybugs, bees, wood-boring beetles), around toadstools (Polyporales) and in the flower heads of thistles. Aliens include 18 species in the genera *Drosophila* (8 species) (Bächli et al. 2002, Grassi et al. 2009), *Chymomyza* (4 species) (Band 1994, Carles-Tolra and Andersen 2002, Perju 1959, Trent Band et al. 2005), *Zaprionus* (3 species) (Chassagnard and Kraaijeveld 1991, Monclus 1976, Tsacas et al. 1977), *Scaptomyza* (2 species) (Nicoli Aldini 2005, Nicoli Aldini and Baviera 2002) and *Dettopsomyia* (1 species) (Prevosti 1976) compared to 104 native species.

Ephydridae. Adults are usually associated with moist substrates, especially shores, marshes and wet meadows. Some develop in decomposing matter or excrement, other are leaf miners or parasitoids. Aquatic and semiaquatic habitats are typical of the family. A total of 335 native species occur in Europe with only three alien species - in the genera *Elephantinosoma, Placopsidella* and *Psilopa* (Gatt and Ebejer 2003).

Fanniidae. Species inhabit forests, rarely open landscape and wetlands. Larvae are generally saprophagous and mostly feed on decaying organic matter as human or animal faeces, decaying material in gardens, and rotting leaf litter. Some species have been reared from fungi, others occur in bird nests, burrows of vertebrates, and nests of social Hymenoptera. There is only one alien species, *Fannia pusio* (Carles-Tolra and Andersen 2002), compared to 82 native species.

Heleomyzidae. Larvae develop in sporocarps of fungi or live in association with mycelia in forest soil, some are necrophagous or saprophagous. There is only one alien species, *Prosopantrum flavifrons* (Ismay and Smith 1994) compared to 145 native species

Hippoboscidae. Adults are bloodsucking ectoparasites of birds and mammals. Females of all species are macrolarviparous, i.e. retaining the larva in the uterus to the end of the third instar. There is only one alien species, *Crataerina melbae* (Popov 1995), compared to 29 native species.

Milichiidae. Larvae are saprophagous and develop in decaying vegetation, wood detritus, in nests of birds, ants (myrmecophilous species) and of other social insects, but also in excrements, carrion, dead insects and snails. Adults of some species are commensals or *kleptoparasites* of predatory insects and spiders. There are two alien species, in the genus *Desmometopa* (Roháček (2006b)), compared to 41 native species.

Muscidae. Larvae develop in various kinds of decaying organic matter, often showing facultative or even obligatory carnivorous behaviour. Larvae of some species appear to be predaceous during their entire larval life. Adults feed on nectar or plant sap, sometimes also on decaying liquids and some species are predaceous. Some species are adapted to anthropogenically-altered ecosystems. Blood-sucking species are of medical and veterinary importance, being vectors of some diseases. There are two alien species, the sorghum pest *Athrerigona soccata* (Vercambre et al. 2000), and a predator of house flies, *Hydrotaea aenescens* (Rozkošný 2006, Saccà 1964), compared to 585 native species.

Phoridae. Adults are found in all types of terrestrial habitats, particularly in forests and meadows but also in steppe-like and xerothermic sites. Food preferences of larvae appear to be remarkably different. Most species are *polysaprophagous* with different degrees of specialisation. Parasitic species are often found in the nests of ants and termites. Some fungus breeders feed on the fungi but others are obligate predators or parasitoids of other fungus feeders such as larval Sciaridae. There are nine alien species in the genera *Megaselia* (three species) (Campobasso et al. 2004, Disney 2008, Disney and Durska 1999), *Chonocephalus* (two species) (Disney 1980, Disney 2002), *Dohrniphora* (two species) (Disney 2002, Disney 2004), *Hypocerides* (one species) (Disney 2004), and *Puliciphora* (one species) (Disney 1983) in comparison to a total of 596 native species.

Sphaeroceridae. Larvae and adults are saprophagous. Larvae develop in diverse organic matter and feed as saprophages on microorganisms destroying rotting plants, dung, carrion or fungi and also on the decomposed liquid substances. Adults occur in all habitats that contain the breeding media of the larvae, preferably in damp places. A few polyphagous species are *synanthropic*, living near human habitats. Many coprophagous species develop in dung heaps near stables or in pastures. There are four alien species, belonging to the genera *Thoracochaeta* (two species feeding on seaweeds) (Roháček and Marshall 2000), *Coproica* (one species) (Carles-Tolra and Andersen 2002), and *Trachyopella* (one species) (Roháček (2006a)), in comparison to a total of 253 native species.

Stratiomyidae. Terrestrial and aquatic larvae of this family live as scavengers. Adults feed on nectar of flowers, exploiting a wide range of flowering plants, especially umbels alongside water margins but also in open sunny places. There are two alien species, the scavenger *Hermetia illucens* (Venturi 1956), which has been used to control house fly, and a soldier fly, *Exaireta spinigera* (Lapeyre and Dauphin 2008), compared to a total of 138 native species.

Tachinidae. Larvae live as endoparasitoids of arthropod larvae. Many species are parasitoids of important pests of agricultural crops and forest trees and are regarded as economically beneficial. Aliens include 8 species of different genera (*Blepharipa, Catharosia, Clytiomya, Phasia, Leucostoma, Sturmia, Trichopoda* and *Zeuxia*) (Carles-Tolra and Andersen 2002, Cerretti 2001, Clemons 2001, Colazza et al. 1996, Vaňhara et al. Tschorsnig 2006) in comparison to a total of ca. 870 native species.

Tephritidae. So called “fruit flies” because larvae of most species inhabit the fruits or other seed-bearing organs of flowering plants. Larvae are phytophagous, some being leaf miners and stem-borers and others developing in roots. Many species are associated with Asteraceae. Adults feed on pollen and nectar. Some species are pests but others are used as biological control agents of weeds. Aliens include 4 species in the genus *Rhagoletis* (3 species) (Duso 1991, Lampe et al. 2005, Merz 1991) and the major fruit pest *Ceratitis capitata* (see factsheet 14.28) in comparison to a total of 264 native species.

Ulidiidae. The biology and immature stages are largely unknown. Adults occur in dry, sunny habitats, such as steppe meadows, and thin steppe forests. Larvae are mostly saprophagous and develop in rotting matter, under bark or in dung but a few seem to be phytophagous. Adults live in marshland habitats, woodland areas, sandy, salty or steppe meadows. They are often observed on flowers, shrub leaves, tree trunks, and on excrement and manure heaps. There are only two aliens, compared to a total of 106 native species, *Euxesta pechumani*, living on carrion and dung (Delage 1969) and *Euxesta notata* living on bulbs (such as onions) and sometimes considered as a pest (Martinez, unpublished).

Suborder Nematocera

Cecidomyiidae. Larvae of gall midges are either phytophagous, zoophagous or mycophagous. Phytophagous species cause galls on various parts of their host plants (hence the common name “gall midges“) but some larvae live free in flower heads or in the stems without making galls, or in conifer cones, or are associated with cambium layers of various trees. Some gall-causing species are serious pests of cultivated plants and forest trees. The zoophagous larvae are predators of the larvae of other gall midges, aphids, mites, coccids, and other arthropods and some of them are used for biological control of pests. Larvae of several species are endoparasites of aphids, psyllids and tingids. This is the dominant group of aliens in Diptera with 23 species (see Table 10.1 for references) but altogether 1800 native midge species are known to occur in Europe.

Culicidae. Larvae develop in water. Females of most species are haematophagous and feed by sucking the blood of vertebrates, whereas males may feed on flower nectar. Adults may transmit various disease pathogens, viz. viruses, malaria and filarioses. Most Culicidae are distributed in tropical and subtropical areas of the world. Whereas the European native fauna only includes 93 species within this family, seven alien species have established in Europe: two species belonging to the genus *Aedes* (the Asian tiger mosquito, *A. albopictus*- see factsheet 14.27, and the Asian rock pool mosquito, *A. japonicus* (Schaffner et al. 2009)); three Asian species of the genus *Culex* (Adhami 1987, Ramos et al. 1998, Samanidou and Harbach 2003) and two species of *Ochlerotatus* (Romi et al. 1999, Schaffner et al. 2001). *Aedes aegypti*, the vector of yellow fever which has been present in Europe for a long time, now seems to be extinct; no exotic species of *Anopheles* has yet established (Schaffner et al. 2001).

Mycetophilidae. Larvae are mycophagous, feeding on the mycelia or fruit bodies of various fungi or myxomycetes. Adults fly in the undergrowth of forests, on meadows and steppe habitats. There is only one alien species, *Leia arsona* (Halstead 2004) compared to a total of ca. 950 native species.

Sciaridae. Larvae are mostly free living in the upper soil layer of nearly all terrestrial habitats. Some species develop inside plant stems, leaves or decaying wood. They feed on fungal mycelia or decomposing plant tissue. There is only one alien species, *Bradysia difformis* (White et al. 2000), compared to a total of 629 native species.

10. 3. Temporal trends of introduction in Europe of alien Diptera

The date of the first record in Europe is more or less precisely known for 84 (ie., 86%) of the alien species of Diptera, whilst it remains unknown for the other 14 species (Table 10.1). Considering, cautiously, this first record in Europe as a proxy, the arrival of alien dipterans showed a significant, exponential acceleration since the second half of the 20th century (Figure 10.2). The mean number of new records per year increased from 0.25 during 1900–1950 to 2.2 during 2000–2008. In parallel, an increasing diversification of the dipteran families involved in the arrivals was observed.

Only a few aliens, mostly Cecidomyiidae, were newly recorded during the 19th century. Probably originating from the subtropics, the midge *Feltiella acarisuga* was first found and described in France in 1827 (Vallot 1827) . It was subsequently discovered in several other European countries to be finally introduced intentionnally in a large part of the world as a biological control agent for red spider mites in greenhouses. Four more alien dipterans, of which three midges and one fruit fly, were subsequently recorded during the second half of the 19th century, each showing different patterns of

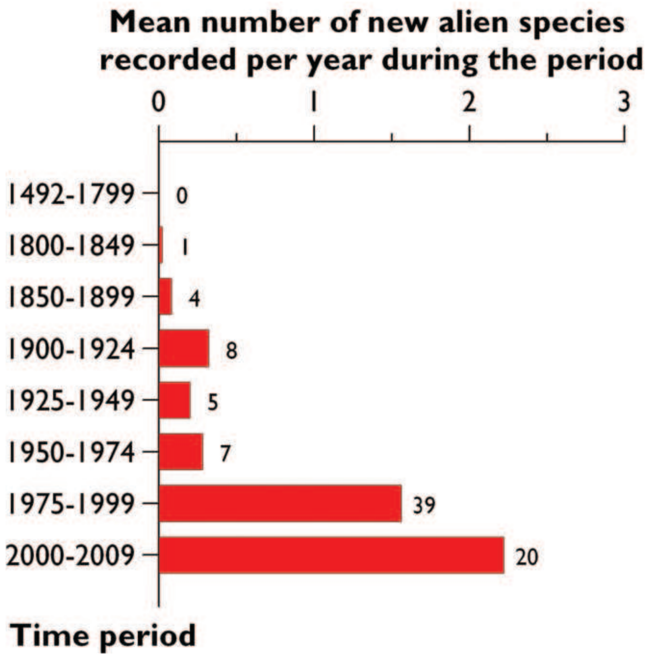

Figure 10.2. Temporal changes in the mean number of records per year of dipteran species alien *to* Europe from 1800 to 2009. The number over each bar indicates the absolute number of species newly recorded per time period.

expansion in Europe. *Contarinia quinquenota* (Cecidomyiidae), developing in flower buds of *Hemerocallis fulva* (Liliaceae), was first found in Austria in 1885 (Löw 1888 and subsequently in 11 other countries. *Clinodiplosis cattleyae* (Cecidomyiidae), which forms conspicuous swellings on the aerial roots of *Cattleya* species (Orchidaceae), was first observed in England in 1885 but later only in France (Molliard 1902). *Orseolia cynodontis* (Cecidomyiidae) was first observed in 1892 in Italy (Massalongo 1892) and then in three other countries. The fruit fly *Ceratitis capitata* (Tephritidae) was discovered in Italy in 1873 and subsequently in 15 other European countries.

The first half of the 20th century saw the arrival of 13 more alien dipterans of which six are Cecidomyiidae, five Drosophilidae, one Calliphoridae and one Stratiomyidae. Two of these species have not shown any expansion in Europe. A cecidomyiid from tropical Asia, *Procontarinia matteiana*, was only first observed in 1906 within the Botanical Garden of Palermo (Sicily), galling leafs of a plant imported from India, *Mangifera indica* (Anacardiaceae) (Kieffer and Cecconi 1906). According to recent information, the host plant has subsequently died out; this alien midge may be considered as extinct in Europe. Discovered in England in 1913, a North American midge, *Rhopalomyia grossulariae*, causing galls on *Ribes grossularia* (Grossulariaceae), has not been found anywhere else since that time (Theobald 1913). On the contrary, an other North American midge, *Janetiella siskiyou* (=*Craneiobia lawsonianae*), which develops in cones of *Chamaecyperis lawsoniana* (Cupressaceae), was first observed in the Netherlands in 1931 (Meijere 1935) and subsequently in 10 further countries. A gall midge of Asian origin, *Rhopalomyia chrysanthemi*, damaging leaves of cultivated *Chrysanthemum* (Asteraceae), was observed in France and Denmark in 1935 (Bovien 1935) and subsequently found in greenhouses of eight more countries. An other Asian midge, *Stenodiplosis panici*, developing in inflorencesces of *Panicum miliaceum* (Poaceae), was discovered in southern Russia in 1926 (Dombrovskaja 1936) and then in four other countries. The African predatory midge, *Dicrodiplosis pseudococci,* attacking the scale *Planococcus citri* (Pseudococcidae) was found in Italy in 1914 (Felt 1914) and then in Spain. Five *Drosophila* species of unknown origin were first found in Great Britain in 1900 and then in several countries of northern and central Europe. The cryptogenic *Chrysomyia albiceps* (Calliphoridae) was recorded in 1927 in France (Mercier 1927) and later expanded to most of southwestern and central Europe. Finally, a Stratiomyidae, *Hermetia illucens*, was first discovered in Malta in 1936 but subsequently spread to 6 more countries (Venturi 1956).

The second half of the 20th century consisted of two distinct periods of invasion of alien dipteran species. From 1950 to 1974, only seven new alien species (i.e. 0.2 species per year on the average) were recorded. They belong to families Cecidomyiidae (*Contarinia citri* (Genduso 1963) and *Stenodiplosis sorghicola* (Starostin et al. 1987), both of African origin), Dolichopodidae (*Micropygus vagans* found in Great Britain in 1970 (Chandler 2004)), Muscidae (a north American predator of house fly, *Hydrotaea aenesecens* (Saccà 1964)), and Sciaridae (*Bradysia difformis* recorded from Great Britain in 1965 (White et al. 2000) and subsequently found in Northern Europe). In contrast, a total of 39 alien species were subsequently observed in Europe from 1975 to 1999 (i.e. 1.6 species per year on the average). These later invasions involved a much larger number of dipteran families than previously. By order of importance, families include Drosophilidae (eight species), Cecidomyiidae (six species), Culicidae (six species among which the tiger mosquito, *Aedes albopictus,* arrived in 1979 in Albania (Adhami 1987)), Phoridae (five species, including the mushroom pest *Megaselia tamilnaduensis* in 1999 (Disney and Durska 1999), Tachinidae (three species), Tephritidae (three species of *Rhagoletis* fruit pests), Agromyzidae (three species among which the crop pests *Liriomyza trifolii* in 1979 (Aguilar & Martínez 1979) and *L. huidobrensis* in 1989 (Trouvé et al. 1991)), and one species in the families Braulidae, Heleomyzidae, Hippoboscidae, Muscidae, and Mycetophilidae. Since 2000, alien dipterans were observed in Europe at a proportionally higher rate, with 20 species newly recorded from 2000 to 2009, i.e. an average of 2.2 species per year. In addition to families already represented by alien species such as Phoridae (four species) (Disney 2002, Disney 2004), Cecidomyiidae (four species among which the quickly spreading *Obolodiplosis robiniae* galling *Robinia pseudoacacia* (Duso C and Skuhrava 2003) - see factsheet 14.26) (Calvo et al. 2006, Gagné 2004, Harris and Goffau 2003), Drosophilidae (three species), Agromyzidae (two species) (Bella et al 2007, Süss 2001), Culicidae (Schaffner et al. 2003), Stratiomyidae (Lapeyre and Dauphin 2008) and Ulidiidae (one species each) (Martinez, unpublished), representatives of two new families were observed: Ephydridae shore flies (three species mostly linked to poultry dung) (Gatt and Ebejer 2003) and Canacidae (one species) (Irwin et al. 2001).

10. 4. Biogeographic patterns of the dipteran species alien *to* Europe

10.4.1. Origin of alien species

A region, or more simply a continent, of origin could be traced for only 78 of the 98 dipteran species alien *to* Europe, i.e. in ca. 80% of the species. However, in a number of cases, the origin of the dipteran species could only be assumed from that of its host. Several species of Cecidomyiidae illustrate the difficulties and uncertainties in assigning origins. Some species were found and described for the first time in Europe but it is likely that they are non-native and introduced together with their host. For example, the Asian origin of a gall midge *Procontarinia matteiana,* first described in Sicily (Kieffer and Cecconi 1906), and the African origin of *Orseolia cynodontis,* another gall maker on *Cynodon dactylon* (Poaceae), first discovered at Verona (Italy) (Massalongo 1892), were assumed from the source of their host plants, imported from India and North Africa, respectively. Similarly, that of *Dicrodiplosis pseudococci*, a predator midge of a scale, *Planococcus citri* (Pseudococcidae), also discovered in Sicily (Felt 1914), was assumed from the subtropical and tropical origin of its insect prey. The cases of *Rhopalomyia grossulariae* and *Dasineura gibsoni* are even more complex. The larvae of *Rhopalomyia grossulariae* which develop in enlarged, deformed leaf buds of *Ribes uva-crispa* (Grossulariaceae) were first discovered in Ohio (USA) and were later found in Great Britain (Theobald 1913); specimens of *Dasineura gibsoni* were described developing in flower heads of *Cirsium arvense* (Asteraceae) in Ottawa, Canada (Gagné 1989), before being also found in Great Britain (Harris 1976). Both species were thus considered to be native of the Nearctic, and then introduced to Europe. However, both host plants are not Nearctic species but *archaeophytes* of Eurasian origin. Therefore, *R. grossulariae* as well as *D. gibsoni* might also be of such origin. However, neither larvae nor adults of these two species have been discovered in continental Europe until now. Further genetic studies may contribute to tracking the exact origin of such species.

In contrast to the general trend observed for arthropods and insects, North America appears to be the dominant contributor of the alien dipteran fauna, with almost one-third of the species originating from this continent, far beyond Asia whilst a significant percentage of species came from Africa (Figure 10.3).

The 30 alien species originating from North America consists of Cecidomyiidae (10 species), Drosophilidae (6 species), Sphaeroceridae (3 species), Tephritidae (3 species; the fruit fly pests *Rhagoletis completa*, *R. cingulata* and *R. indifferens*), Ulidiidae (2 species), and Agromyzidae, Canacidae, Culicidae, Muscidae, Stratiomyidae, and Tachinidae (one species each). The insects originate from various part of this large continent; for example *Janetiella siskiyou* (Gagné 1972) and *Resseliella conicola* (Gagné 1989, Skuhrava et al. 2006) developing in cones of *Abies* and other conifers (Pinaceae) from the northwestern region whereas *Obolodiplosis robiniae* and *Dasineura gleditchiae* (Gagné 1989) developing in leaflet galls on *Gleditsia triacanthos* (Fabaceae) arrived from the northeast.

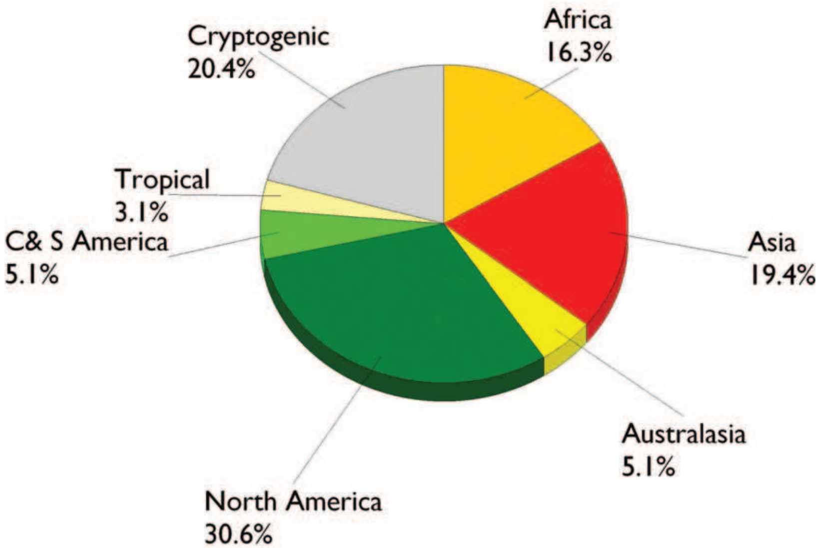

Figure 10.3. Origin of the 98 species of Diptera alien *to* Europe.

The 19 dipteran species coming from Asia consists of six species of Cecidomyiidae, five species of Culicidae, two species of Agromyzidae, Phoridae and Tachinidae, and one species of Drosophilidae and Ephydridae. Most species originate from the temperate, eastern Asia such as *Contarinia quinquenotata* damaging flower buds of *Hemerocallis fulva* (Liliaceae), *Epidiplosis filifera*, a predator of the coccid scale *Ceratoplates floridensis* on citrus fruits (Nijveldt 1965), and probably *Rhopalomyia chrysanthemi* (Cecidomyiidae) (Barnes 1948) whilst *Cerodontha unisetiorbita* (Agromyzidae) (Süss 2001), *Aedes japonicus* (Culicidae) (Schaffner et al. 2009) and *Drosophila curvispina* (Drosophilidae) (Bächli et al. 2002) originate from Japan. However, tropical Asia, mainly India, has also contributed to the alien entomofauna, having supplied *Aedes albopictus* (Eritja et al. 2005), *Culex tritaebiorhynchus* (Samanidou and Harbach 2003), *C. vishnui* (Culicidae) (Adhami 1987), *Placopsidella phaenota* (Ephydridae) (Gatt and Ebejer 2003), *Procontarinia matteiana* (Kieffer and Cecconi 1906), *Horidiplosis ficifolii* (Cecidomyiidae), causing leaf galls on *Ficus benjamina* (Moraceae) (Harris and Goffau 2003), and *Megaselia tamilnaduensis* (Phoridae) (Disney and Durska 1999). A few species came from Middle East (*Leucostoma edentata;* Tachinidae) (Chassagnard and Kraaijeveld 1991) and Western Asia (*Ochlerotatus subdiversus*; Culicidae) (Schaffner et al. 2001).

The 16 species coming from Africa consist of Cecidomyiidae (five species), Drosophilidae (three *Zaprionus* species), Phoridae (three species), Ephydriidae (two species), and one species of Tephritidae (*Ceratitis capitata*), Culicidae and Mycetophilidae. In addition to the species mentionned above (*D. pseudococci* and *O. cynodontis),* midges include *Stenodiplosis sorghicola* associated with *Sorghum* (Poaceae), and *Contarinia citri* developing in flower buds of *Citrus* sp. (Rutaceae), which probably originates from Mauritius. The Phoridae species came from tropical Africa.

Five alien dipteran species of different families are known to originate from Central and South America. They include *Clinodiplosis cattleyae* (Cecidomyiidae) from Brazil (Gagné 1994), *Liriomyza huidobrensis* (Agromyzidae) from South America (Trouvé et al. 1991) before having been introduced in Central America, Asia and Africa, *Fannia pusio* (Fanniidae) (Hill et al. 2005), *Prosopantrum flavifrons* (Heleomyzidae) (Ismay and Smith 1994), and the recently- arrived, *Phytoliriomyza jacarandae* (Agromyzidae) (Bella et al 2007).

Another 5 dipteran species originate from Australasia, viz. *Micropygus vagans* (Dolichopodidae) from New Zealand (Chandler 2004), *Megaselia gregaria* (Phoridae) from Tasmania (Disney 2002), *Coproica rufifrons* (Sphaeroceridae) from Papua-New Guinea (Carles-Tolra and Andersen 2002), *Exaireta spinigera* (Stratiomyidae) from Australia (Lapeyre and Dauphin 2008), and *Dohrniphora cornuta* (Phoridae) from Australasia (Disney 2002).

Three other dipteran species are only known to originate from the tropical and subtropical parts of the world. They include *Dettopsomyia nigrovittata* (Drosophilidae), which has been found only once in Canary islands (Prevosti 1976), *Puliciphora borinquenensis* (Phoridae), found only once in Great Britain (Disney 1983) and *Megaselia scalaris* (Phoridae), a saprophagous species which may be dangerous to human health and has largely spread in western and central Europe (Disney 2008).

10.4.2. Distribution of alien species in Europe

Alien dipteran species and families are not evenly distributed throughout Europe. Large differences exist between countries in the number of alien species present within each territory (Figure 10.4). As for the other arthropod groups, it may reflect differences in sampling intensity and in the number of local taxonomists specialized in these families.

The number of alien dipterans is significantly and positively correlated with the country surface area (after log-transformation; P= 0.0282). Indeed, Great Britain hosts the largest number of aliens (36 species of 11 families), followed by continental Spain (33 species; 17 families), continental France (29 species; 13 families) and continental Italy (28 species; 11 families). However, the family diversity is similar in three countries of Central Europe of much smaller size, the Czech Republic, Switzerland, and Slovakia which host each 11 families of alien dipterans for ca. 20 species. Although the western and southern countries seem to host more aliens (Figure 10. 4), the number of species per country relatively to their size is not correlated with longitude (P= 0.4106) nor with latitude (P= 0.3896). The European islands host proportionally more alien dipterans than continental countries relatively to their size (Kruskall- Wallis test on the number of aliens per km^2; P=0.0098). Thus, 14 alien species of 10 families were found in the small island of Malta occupying 316 km^2 in the Mediterranean Sea.

Most alien dipterans still have a very restricted distribution. More than 30% of the species (30 species) have been observed in only one country such as *Culex deserticola* (Culicidae) and *Dohrniphora papuana* (Phoridae) as yet only recorded from Spain

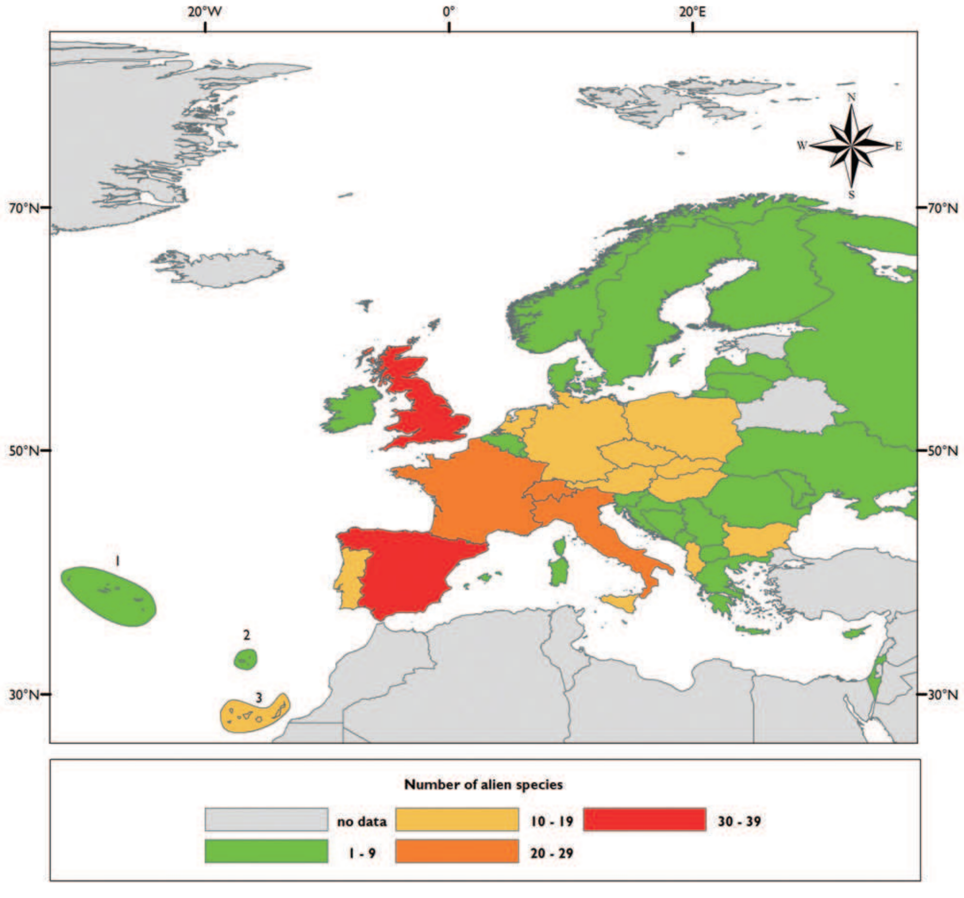

Figure 10.4. Comparative colonization of continental European countries and islands by dipteran species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

(Disney 2004, Eritja et al. 2000, Ramos et al. 1998), *Chymomyza wirthi* (Drosophilidae) in Great Britain (Gibbs 1994), *Placopsidella phaenota* (Ephydridae) in Malta (Gatt and Ebejer 2003), and *Exaireta spinigera* (Stratiomyidae) in France (Lapeyre and Dauphin 2008). Another 17 species are present in only two, often nearby, countries such as *Cerodontha unisetiorbita* (Agromyzidae) found in Italy and Albania (Süss 2001), *Drosophila suzukii* (Drosophilidae) in Spain and Italy (EPPO 2010) and *Culex tritaeniorhynchus* (Culicidae) in Albania (Adhami 1987) and Greece (Samanidou and Harbach 2003). No alien Diptera is present in more than 24 of the 65 countries and large islands of Europe. Only 9 species have been introduced or have expanded in 15 countries or more. Most are plant pests such as the agromyzid leaf miners *Liriomyza huidobrensis* (24 countries) (EPPO 2006, Fauna Europaea) and *L. trifolii* (22 countries) (Fauna Europaea), a midge *Obolodiplosis robiniae* (20 countries) (Glavendekić et al. 2009), and a fruit fly *Ceratitis capitata* (20 countries) (Fauna Europaea). The Tiger mosquito, *Aedes albopictus*, and the predator midge, *Feltiella acarisuga* are also present in 13 and 21 countries, respectively. In most cases, it is not known whether the species has expanded naturally once established in a country or if the extended distribution corresponds to repeated introductions from abroad. However, very patchy distributions probably result from independent introductions. Thus, *Hypocerides nearcticus* (Phoridae) was found in Spain and Sweden (Disney 2004), and *Coproica rufifrons* (Sphaeroceridae) in Malta and in the Canary islands (Carles-Tolra and Andersen 2002). In contrast, the occurence of an alien species within a whole geographic region is likely to proceed, at least partly, from natural dispersion such as for *Pelomyia occidentalis* (Canacidae) which is currently present throughout Central Europe (Czech Republic, Germany, Hungary, Poland and Slovakia) (Roháček (2006a), Roháček (2006c)). Some other species are known to combine both methods of dispersal. *Aedes albopictus* was introduced independently by human activity in Albania, France, Italy, Netherlands but probably spread naturally along the Adriatic coast (see map on factsheet 14.27). The honeylocust gall midge, *Obolodiplosis robiniae,* also spread very rapidly throughout Europe (Glavendekić et al. 2009). Four years after its discovery in Italy in 2003, it occupied a large area from southern England in the west to eastern Ukraine in the east and from northern Germany to southern Italy (see map on factsheet 14.26).

Dipterans alien *in* Europe, i.e. originating from one part of Europe and introduced through human activity in an other part, are a matter of debate because it is often difficult to discriminate between a natural expansion, an introduction, or simply a lack of previous information regarding the actual species‘ native range. Table 10.2 present some of these species. They include species of Mediterranean origin, likely to have been introduced with their Mediterranean hosts in more northern countries, for example *Monarthropalpus flavus,* a gall-maker of common box (*Buxus sempervirens*) in Central-European countries. In addition, the date of first record is likely to differ largely from the date of arrival for a few species specifically associated with *archaeophyte* plants. For instance, two gall midges, *Contarinia pisi* and *C. lentis,* specifically galling plants in the family Fabaceae, *Pisum sativum* and *Lens culinaris* respectively, have been recorded in Europe only rather recently, although their host plants have been introduced for cultivation since the prehistoric times, probably from the Mediterranean region or the Middle East. Other species followed their host plant introduced from continental Europe to islands on which the plant was absent. Dipterans specifically related to larch such as several species of *Strobilomyia* larch cone flies (Anthomyiidae) (Ackland 1965; Roques, unpubl.) and a larch gall midge, *Dasineura kellneri* (Hill et al. 2005) or to spruce (a spruce cone gall midge, *Kaltenbachiola strobi*) (Hill et al. 2005) are thus considered to be alien *in* Great Britain.

10.5. Main pathways of introduction to Europe of alien dipteran species

Intentional introductions represent a much smaller proportion of alien arrivals in Diptera than the average in arthropods in general (3.1% vs. 10%). Only three dipteran predators of different families were introduced intentionally for biological control and have subsequently become established. Two of them, *Hydrotaea aenescens* (Muscidae) and *Hermetia illucens* (Stratiomyidae), were released from North America to control houses flies in poultry farms and stables (Saccà 1964). The third species, *Feltiella acarisuga* (Cecidomyiidae), is a cryptogenic species of cosmopolitan distribution preying exclusively on tetranychid red spider mites. Larvae and adults were found in several countries of Europe, in northern Africa, Asia, North America, Australia and New Zealand. It has been intentionally released, mostly in glasshouses, in Italy, Denmark and Poland, to protect crops.

Similarly, as for the other taxa, trying to identify pathways for the remaining 97% of accidental introductions is not a straightforward task. In a number of cases, it however could be inferred from the species biology, for that of the plant/animal host or from repeated interceptions with merchandise at borders. Thus, eggs and larvae of the Asian tiger mosquito, *Aedes albopictus,* and those of the Asian rock pool mosquito*, A. japonicus*, have been shown to be imported as stowaway through the trade of second-hand tyres (Reiter 1998, Schaffner et al. 2009). Larvae of *A. albopictus* were also found inside bags watering "lucky bamboos" (*Dracaena senderiana*) for horticultural markets. Larvae, such as these of *Liriomyza* spp., that are leaf-miners of vegetable crops, are regularly intercepted at borders along with agriculture imports, as well as fruits infested by larvae of *Ceratitis capitata* and *Rhagoletis* spp.

More generally, pathways can be hypothesized for about a half of the 95 alien Diptera which were accidentally introduced. Horticultural and ornamental trade is probably the most significant pathway, with a total of 30 species more or less closely associated. *Horidiplosis ficifolii,* a midge causing leaf galls on *Ficus benjamina* (Moraceae) was probably imported with infected fig plants in containers from South-eastern Asia (Taiwan) as well as the midge *Asphondylia buddleia*, developing in swollen aborted flowers of *Buddleia racemosa* (Scrophulariaceae), from El Salvador to southern France (Beguinot 1999). A similar process is likely to have occurred for the agromyzids *Cerodontha unisetiorbita* with *Phyllostachys* bamboos imported from south Asia (Süss 2001), and *Phytoliriomyza jacarandae* developing on ornamental blue Jacaranda trees (*Jacaranda mimosifolia*) introduced to Sicily and mainland Italy (Bella et al. 2007). Some other gall midges are assumed to have been transported to Europe with seedlings of plants for planting as very small larvae hidden in undeveloped plant organs, as for example *Obolodiplosis robiniae, Dasineura gleditchiae, Dasineura oxycoccana* and *Prodiplosis vaccinii,* the two last species developing in bud galls of cultivated species of *Vaccinium* (Ericaceae) in North America (Gagné 1989). Orchid trade was probably responsible for the transport of the midge *Clinodiplosis cattleyae* whereas cone and seed trade can be assumed as the vector of a seed midge, *Janetiella siskiyou*, infesting *Chamaecyprais lawsonniana* (A. Murr.) Parl. and a cone midge, *Resseliella conicola* on *Picea sitchensis* (Bong.) Carrière.

Comparatively few species (10) have larvae that appear to be associated with the trade of vegetable crops (the agromyzids *L. huidobrensis* and *L. trifolii* with a large number of different crops; *L. chinensis* with *Allium;* the cecidomyiids *Stenodiplosis pa-*

nici with *Panicum* and *S. sorghicola* with *Sorghum)* and fruit crops (the midge *Contarinia citri* with *Citrus,* and the tephritids *Ceratitis capitata, Rhagoletis completa, R. cingulata* and *R. indifferens*). The movement of stored products seems responsible for the introduction of another 10 species, mostly drosophilds but also several species associated with the mushroom trade such as the phorids *Megaselia tamilnaduensis* (Disney and Durska 1999) and *M. scalaris* (Disney 2008) and the mycetophilid *Leia arsona* (Halstead 2004). Movement of compost is the problable pathway for two species of Stratiomyidae, *Exaireta spinigera* (Lapeyre and Dauphin 2008) and *Hermetia illuscens* (Venturi 1956). Finally, three species are associated with animal husbandry such as *Crataerina melbae* (Hippoboscidae) (Popov 1995) and *Chonocephalus depressus* (Phoridae) (Disney 2002).

10.6. Ecosystems and habitats invaded in Europe by alien dipteran species

Alien dipterans predominantly exhibit phytophagous habits (35 species- 35.6%). However, zoophagous and detrivorous/mycetophagous species each represent nearly one-third of aliens (28.6% and 29.6%, respectively) whilst the feeding habits remains unknown for ca. 2% of the species. Leaves constitute the most important feeding niche for the alien phytophagous species (24 species), far beyond fruits (10 species including cones and seeds). Leaves are exploited by "true" leaf miners (agromyzids and cecidomyids) and by gall-makers (cecidomyids) but not by external feeders.

About 85 % of the alien Diptera seem to have firmly established in their new European environment and its habitats. However, there is little evidence of the establishment status of the 15 % remaining species which have been recorded only once or twice. Nearly 65% (64.1%) of the alien Dipteran species established in Europe are only present in man-made habitats, essentially around and in buildings, in agricultural lands, parks and gardens and glasshouses (Figure 10.5). This proportion is not significantly different from the average value observed for all arthropods. In addition, 16 of the 35 phytophagous aliens (45.7%) remain strictly related to their original, exotic plants used as ornamentals at the vicinity of human habitations such as *Cerodontha unisetiorbita* on bamboo, *Dasineura gleditchiae* on *Gleditsia*, *Asphondylia buddleia* on *Buddleia*, *Obolodiplosis robiniae* on honey locust *Robinia pseudoacacia*. Woodlands and forests have been colonized by a few alien species (11.7 %). The remaining species occur quite equally in diverse natural and semi-natural habitats, viz. in coastal areas, inland surface waters, mires and bogs, grasslands, and heathlands.

10.7. Ecological and economic impact of alien dipteran species

Like most insects, alien dipteran species are better known for their economic and sanitary impact than for their ecological impact. Indeed, ecological impacts on native fauna and flora are not documented at all for any of the species established in Europe. Nega-

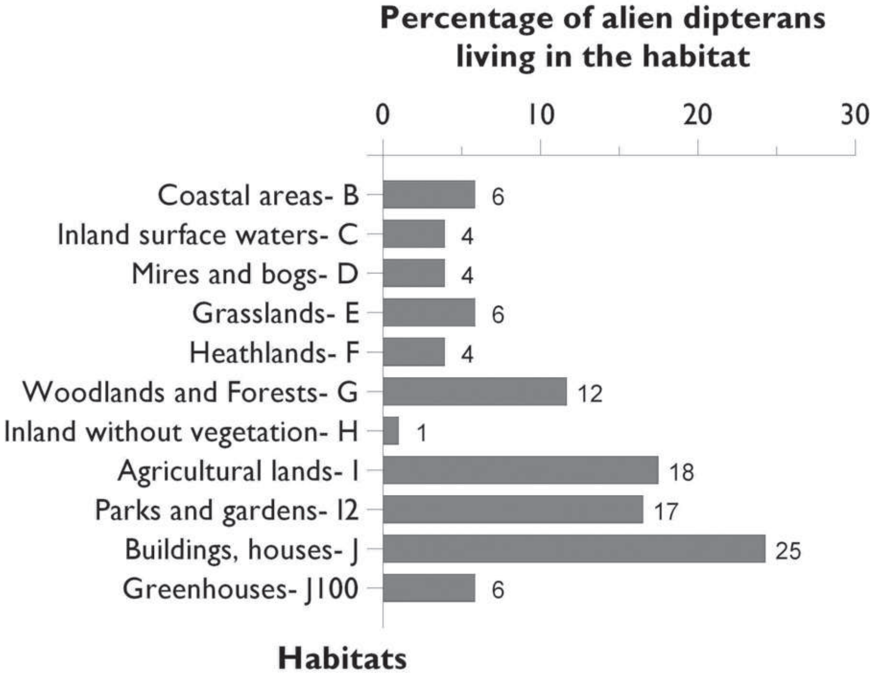

Figure 10.5. Main European habitats colonized by the established alien species of Diptera. The number over each bar indicates the absolute number of alien dipterans recorded per habitat. Note that a species may have colonized several habitats.

tive economic impacts on crops have been recorded for a total of 14 species. They include the agromyzid leaf miners *Liriomyza trifolii* and, more especially, *L huidobrensis*, whose larvae mine a wide range of vegetables and ornamental plants in glasshouses in a large part of Europe but also outdoors in the Mediterranean basin (see factsheet 14.23, 14.24). Of economic importance are also the tephritid fruit flies. *Ceratitis capitata* damage fruits of many host plants and has a large impact on fruit crops, especially citrus fruits and peach, all over the Mediterranean basin but also in some countries of central Europe (see factsheet 14.28). Other fruit fllies in the genus *Rhagoletis*, affect cherry (*R. cingulata* and *R. indifferens*) (Lampe et al. 2005, Merz 1991) and walnut crops (*R. completa*) (Duso 1991, Merz 1991) in Western Europe. The recently introduced *Drosophila suzukii* is also a fruit pest (EPPO 2010). Some mycetophagous species have a local impact on cultivated mushrooms (*Megaselia tamilnaduensis, Megaselia gregaria, and Bradysia difformis*) (Disney 2008, Disney and Durska 1999, White et al. 2000). Two other species of midges, *Stenodiplosis panici* and *Stenodiplosis sorghicola* developing in inflorescences of *Panicum* and *Sorghum,* respectively, may become economic pests in the future if the development conditions become more suitable for outbreaks.

Positive impacts are considered for the 3 dipteran species deliberately introduced to Europe for biological control of house flies and tetranychid mites (see 10.5). However, their possible ecological impact on the native, non-target fauna is not documented.

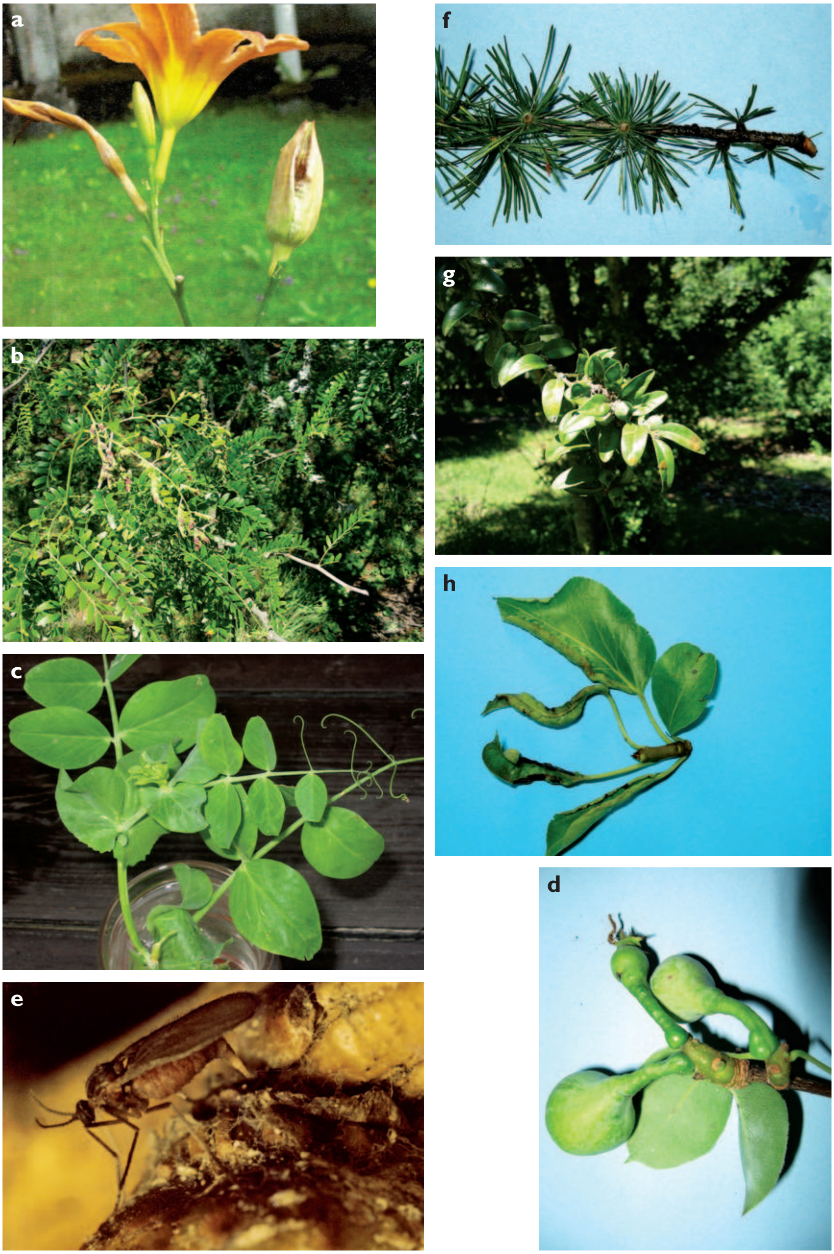

Figure 10.6. Some alien midges and their damage. **a** Unopened and swollen flower bud (right) of *Hemerocallis fulva* caused by larvae of *Contarinia quinquenotata* **b** leaflets of *Gleditsia triacanthos* changed into galls by larvae of *Dasineura gleditchiae* **c** Leaf bud gall on *Pisum sativum* caused by larvae of *Contarinia pisi* **d** Fruits of *Pyrus communis* heavily deformed by larvae of *Contarinia pyrivora* **e** female of *Dasineura kellneri* sitting on the bud of *Larix decidua* and laying eggs **f** Swollen buds of *Larix decidua* capped with resin caused by larvae of *Dasineura kellneri* **g** Galls in form of indistinct shallow blisters apparent on both sides of the leaf of *Buxus sempervirens*, caused by larvae of *Monarthropalpus flavus* **h** Rolled leaf margins of *Pyrus communis* caused by galls of *Dasineura pyri*.

Some other alien predators which have been accidentally introduced such as *Dicrodiplosis pseudococci* and *Epidiplosis filifera*, may be used for biological control of coccids in the future.

A total of 7 alien dipterans may have a sanitary impact on human and animal health. Six of the 7 introduced species of mosquitoes in the family Culicidae are capable of transmitting diseases through female bites (Taylor et al. 2006). The most important one, *Aedes albopictus,* is now established along the Mediterranean coast from south eastern France to northern Greece and is the vector of Chykungunya disease as well as many arboviruses, avian plasmodia and dog heartworm filariasis (see factsheet 14.27). Other alien culicids may be vectors of the West Nile virus (*Aedes japonicus* (Schaffner et al. 2009), *Culex tritaeniorhynchus, C. vishnui, O. atropalpus*), Japanese encephalitis (*A. japonicus, C. tritaeniorhynchus*) and Sindbis virus (*C. tritaeniorhynchus*). In addition, a detrivorous phorid, the scuttle fly *Megaselia scalaris*, may be a cause of allergies whilst it is reported in tropical areas to cause wound and intestinal myiasis in humans (Disney 2008).

Besides their measurable economic impact, some other alien dipterans may have an aesthetic impact because their oubreaks drastically changes the foliage of ornamental species in town parks and private gardens, even if the damage occurs on exotic, introduced trees. Such aesthetic impact has been observed for three midges at least, *Dasineura gleditchiae* causing galls on leaflets of *Gleditsia triacanthos* (Dini-Papanastasi and Skarmoutsos 2001), *Obolodiplosis robiniae* causing galls on leaf margins of *Robinia pseudoacacia* (Glavendekić et al. 2009, Skuhravá et al. 2007), and *Contarinia quinquenotata* preventing flowering of *Hemerocallis fulva* in gardens (Halstead and Harris 1990).

References

Aartsen van B (2001) *Rhagoletis indifferens*, een nieuwe boorvlieg voor de Nederlande fauna (Diptera: Tephritidae). *Nederlandse Faunistische Mededelingen* 14: 19–22.

Ackland DM (1965) Two new british species of Anthomyiidae (Diptera) with taxonomic notes on related species. *Entomologist's Monthly Magazine* 100: 136–144.

Aczél M (1944) Die Linsenblütengallmücke (Contarinia lentis n. sp.), ein neuer Linsenschädling. *Növényegészségügyi Evy* 1941–1943: 127–171.

Adhami J (1987). Mushkonjat (Diptera: Culicidae) te Shqiperise, tribu Culicini (in Albanian). *Revista Mjekësore* (1–2) 82–95.

Adhami J, Murati N (1987) [Presence of the mosquito *Aedes albopictus* in Albania] (in Albanian, French summary). *Revista Mjekësore*1: 13–16.

Aguilar J d', Martínez M (1979) Sur la présence en France de *Liriomyza trifolii* Burgess. *Bulletin de la Société Entomologique de France* 84, 143–146.

Ambrus B (1958) [Állatföldrajzi viszgálatok Sopron és környékének gubacsfainájá́n] (In Hungarian) (Zoogeographical bearings of the gall-nuts in Sopron and its surroundings). *Állattani Közlemények* 46: 159–175.

Andreadis TG, Anderson JF, Munstermann LE, Wolfe RJ, Florin DA (2001) Discovery, Distribution, and Abundance of the Newly Introduced Mosquito *Ochlerotatus japonicus* (Diptera: Culicidae) in Connecticut, USA. *Journal of Medical Entomology* 38: 774–779.

Arzone A (1979) L'agromizide neartico *Liriomyza trifolii* (Burgess) nuovo nemico di Gerbera in Italia. *Informatore Fitopatologico* 29: 3–6.

Bächli G (2004) 43. Diptera, Drosophilidae. In: Cerretti P, Hardersen S, Mason F, Nardi G, Tisato M, Zapparoli M (Eds) *Invertebrati di una foresta della Pianu ra Padan a, Bosco della Fontana, Secondo contributo. Conservazione Habitat Invertebrati, 3.* Verona: Cierre Grafica Editore. 304 pp.

Bächli G, Vilela CR, Haring F (2002) Four new species of West Palaearctic Drosophilidae (Diptera). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 75, 299–333

Balas G (1943) Gubacsok Komárom megyéböl III. (Zoocecidien aus dem Komitate Komárom (Ungarn) III. *Botanikai Közlemmények* 40: 286–290.

Ball SG, Morris RKA (2000) Provisional atlas of British hoverflies (Diptera, Syrphidae). Huntingdon, UK: Biological Records Centre. 168 pp.

Band HT (1994) *Chymomyza procnemoides* Wheeler (Diptera: Drosophilidae): Will it Succeed as a Biological Invader? *Global Ecology and Biogeography Letters* 4: 65–68.

Barnes HF (1948) *Gall Midges of Economic Importance. Vol. 4. Gall midges of ornamental plants and shrubs*. London: Crosby Lockwood and Son. 165 pp.

Bathon H (2007) Die Robinien-Gallmücke Obolodiplosis robiniae (Haldeman) (Diptera: Cecidomyiidae) in Deutschland. *Hessische Faunistische Briefe* 26: 51–55.

Baudyš E (1947) [The sixth contribution to the zoocecidiological investigations of Moravia and Silesia] (in Czech, English abstract). *Sbornik Vysoke školy zemědělské Brno* 1947: 1–55.

Beguinot J (1999) Présence d´un Asphondylia (Diptera, Cecidomyiidae), gallicole sur fleurs de Buddleja, nouveau pour la France. *Bulletin de la Société Linnénne de Bordeaux* 27: 81–86.

Behr L (1949) Auch Pflanzen werden krebskrank. *Natur und Technik* 3: 184–188.

Bella S, Mazzeo G, Süss L (2007) First record for the European fauna of *Phytoliriomyza jacarandae* Steyskal & Spencer, 1978 (Diptera Agromyzidae) leafminer of *Jacaranda mimosifolia* D. Don. (Bignoniaceae). *Bollettino di Zoologia Agraria e di Bachicoltura Ser II* 39: 75–78.

Berest ZL, Titar VM (2007) Robinieva krajova galicja (*Obolodiplosis robiniae*) (Diptera, Cecidomyiidae), mozlivist podalsogo rozsirennja arealu v Ukraini. *Karantin i Zachist Roslin* 7: 24–26.

Beschovski V, Karadjova O (1996) The South American leafminer *Liriomyza huido*brensis Blanch. (Diptera: Agromyzidae) - a new pest in Bulgarian greenhouses. *Acta Entomologica Bulgarica* 2: 5–11.

Beschovski V, Langourov M (1997) Contribution to the study of the distribution of Phoridae species in the Balkan Peninsula. *Acta zoologica bulgarica*, 49: 43–47.

Blauvelt WE (1939) Rose midge investigations. *American Rose Annual* 1939: 114–117.

Bolchi Serini G, Volonté L (1985) *Dasineura gleditchiae* (Osten Sacken), Cecidomide nuovo per l´Italia (Diptera, Cecidomyiidae). *Bollettino di Zoologia agraria e di Bachicoltura Ser. II* 18: 185–189.

Bosio G, Bogetti C, Brussino G, Gremo F, Scarpelli F (1998) [*Dasineura oxycoccana*, a new pest of blueberry (*Vaccinium corymbosum*) in Italy] (in Italian). *Informatore Fitopatologico* 11: 36–41.

Bourel B, Tournel G, Hédouin V, Gosset D (2004) Entomofauna of buried bodies in northern France. *International Journal of Legal Medicine* 118: 215–20.

Bovien P (1935) Chrysanthemum-galmyggen (*Diarthronomyia hypogaea* F. Löw). *Gartner Tidende* 1: 5–6.

Bozicic B (1987) Mountain fauna and geographical analysis of mosquitoes (Diptera, Culicidae) inhabiting the area from Pannonian depression to the Adriatic sea (Yugoslavia). *Biologia Gallo-hellenica* 13: 141–144.

Buhr H (1939) Pflanzengallen Mecklenburgs IV. *Archiv der Freunde der Naturgeschichte Mecklenburgs NF* 14: 29–70.

Calvo D, Molina JM, Skuhravá M (2006) *Prodiplosis vaccinii* an introduced pest of blueberries in southwestern Spain. *Acta Horticulturae (ISHS)* 715: 519–524.

Campobasso CP,Henry R, Disney L, Introna F (2004) A Case of *Megaselia scalaris* (Loew) (Dipt., Phoridae) breeding in a human corpse. *Anil Aggrawal's Internet Journal of Forensic Medicine and Toxicology* 5: 5731.

Carles-Tolra M, Andersen H (2002). *Catálogo de los Diptera de España, Portugal y Andorra*. Monografias de la Sociedade Entomológica Aragonesa vol. 8. Saragoza: Sociedad Entomológica Aragonesa. 323 pp.

Cerný M (2006) *Liriomyza huidobrensis*. *In: Mlíkovský J, Stýblo P (Eds) Nepůvodní druhy fauny a flóry České republiky [Alien species in fauna and flora of the Czech Republic].* Praha: ČSOP, pp. 331–332.

Cerný M, Vála M (2006) Agromyzidae Fallén, 1810. In Jedlička L, Stloukalová V., Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Cerretti P (2001) Note su Tachinidi nuovi per la fauna italiana (Diptera Tachinidae). *Bollettino della Società Entomologica Italiana* 133(2): 153–166.

Chandler P (2004) An Irish invasion. *Stowaways* 4: 14–15.

Chandler P (Ed) 1 (1998) *Checklists of insects of the British Isles.* Handbooks for the identification of British insects (New Series) 12, Part 1 Diptera. London: Royal Entomological Society. 234 pp.

Chassagnard MT, Kraaijeveld AR (1991) The occurence of *Zaprionus* sensu stricto in the Palaearctic region (Diptera: Drosophilidae). *Annales de la Société Entomologique de France* 27: 495–496.

Clemons L (2001) *Phasia* (*Phasia*) *barbifrons* (Girschner, 1887) (Diptera, Tachinidae), a possibly overlooked species new to Britain. *Dipterists Digest* (second series) 8: 3–5.

Clemons L (2009) *Chymomyza amoena* (Loew, 1862) (Diptera, Drosophilidae) new to Britain. *Dipterists Digest* (second series) 16: 21–25.

Colazza S, Giangiuliani G, Bin F (1996) Fortuitous introduction and successful establishment of *Trichopoda pennipes* F., adult parasitoid of *Nezara viridula* (L.). *Biological Control* 6: 409–411.

Coutin R (1965) Une Cécidomyie des fleurs de lentille nouvelle en France. *Phytoma* 170: 19–21.

Coutin R (1969) Récente extension mondiale et présence de la Cécidomye du Sorgho (*Contarinia sorghicola* Coq (1898) en France méridionale (Dipt. Cecidomyidae). *Bulletin de la Société Entomologique de France* 74: 13–20.

Coutin R (1976) Une Cécidomyie nouvelle en France, ravageur des graines du Cypres de Lawson *Janetiella siskiyou* Felt, 1917 (= *Craneiobia lawsonianae* De Meijere, 1935) (Dipt. Cecidomyiidae). *Bulletin de la Société Entomologique de France* 81: 2–8.

Csóka G (2006) Az akác-gubacsszúnyog *Obolodiplosis robiniae* (Haldeman 1847) megjelenése Magyarországon. *Növényvédelem* 42: 663–664.

Dalla Pozza G., Majori G (1992) First record of Aedes albopictus establishment in Italy. *Journal of the American Mosquito Control Association* 8: 318–320.

Dauphin P (1991) Sur la présence en France de *Dasineura gleditchiae* (Diptera, Cecidomyiidae), gallicole sur *Gleditsia triacanthos* (Fabacées, Caesalpinoidae). *Bulletin de la Société Linnéenne de Bordeaux* 19: 126.

Delage A (1969) *Euxesta nitidiventris* Löw, Diptère du Jardin des Plantes. *Annales de la Société d'Horticulture et d'Histoire Naturelle de l'Hérault* 109: 2.

Dewaele P, Leclercq M, Disney RHL (2000) Entomologie et médecine légale: les Phorides (Diptères) sur cadavres humains. Observation inédite. *Journal de Médecine Légale Droit Médical* 43: 569–72.

Dimitrova B, Pencheva A (2004) *Dasineura gleditchiae* (Diptera: Cecidomyiidae) – a new pest of honeylocust in Bulgaria. *Forestry Ideas* 10: 64–69.

Dini-Papanastasi O, Skarmoutsos G (2001) Relative susceptibility of ten honeylocust (*Gleditsia triacanthos* L.) clones to attack by the honeylocust pod gall midge (*Dasineura gleditschiae* Osten Sacken) in Northern Greece. *Proceedings International Conference Forest Research: a challenge for an integrated European approach (2001–08–27/09–01, Thessaloniki, GR),* 333–336.

Disney RHL (1980), An exotic scuttle fly, Chonocephalus heymonsi Stobbe (Diptera, Phoridae), from Middlesex. *Entomologist's monthly Magazine* 116: 207–212.

Disney RHL (1983) *Scuttle Flies: Diptera, Phoridae (except Megaselia)*. Handbooks for the Identification of British Insects 10 (6). London : Royal Entomological Society. 81 pp.

Disney RHL (1991) The aquatic Phoridae (Diptera). *Entomologica Scandinavica* 22: 171–191.

Disney RHL (1994) *Scuttle Flies: The Phoridae*. London: Chapman & Hall. 467 pp.

Disney RHL (2002) Revisionary notes on *Chonocephalus* Wandolleck (Diptera. Phoridae) with keys to species of the Holarctic Region. *Zootaxa* 60: 1–36.

Disney RHL (2004) Two exotic tramp species of Scuttle Fly (Dipt., Phoridae) recorded in Spain. *Entomologist`s Montly Magazine* 140: 307–308.

Disney RHL (2008) Natural History of the Scuttle Fly, *Megaselia scalaris*. *Annual Review of Entomology* 53: 39–60.

Disney RHL, Durska E. (1999) A new subspecies of a scuttle fly (Diptera: Phoridae) that feeds on oyster mushrooms (*Pleurotus ostreatus*) in Poland. *Fragmenta Faunistica* 42: 127–132.

Dittrich R (1913) 4. Fortsetzung des Nachtrages zum Verzeichnisse der Schlessischen Gallen. *Jahresbericht der Schlesischen Gesselschaft für vaterlandische Cultur* 91: 98–129.

Dobson JR (1999) A ‚bee-louse' *Braula schmitzi* Orosi-Pal (Diptera: Braulidae) new to the British Isles, and the status of *Braula* spp. in England and Wales. *British Journal of Entomology and Natural History* 11: 139–148.

Docters van Leeuwen WM (1957) *Gallenboek*. Zutphen: WJ Thieme. 332 pp.

Dombrovskaja E (1936) [On the Cecidomyiid fauna of the Kamennaja Steppe, USSR] (In Russian, English summary). *Trudy Instituta Zoologii, Akademiya Nauk Leningrad* 3: 409–428.

Duso C (1991) Sulla comparsa in Italia di un Tefritide neartico del noce: *Rhagoletis completa* Cresson (Diptera, Tephritidae). *Bollettino di Zoologia Agraria e di Bachicoltura* 23: 203–209.

Duso C, Fontana P, Tirello P (2005) Diffusione in Italia e in Europa di *Obolodiplosis robiniae* (Haldeman), dittero cecidomiide neartici dannoso a *Robinia pseudoacacia*. *Informatore fitopatologico* 5: 30–33.

Duso C, Skuhrava M (2003) First record of *Obolodiplosis robiniae* (Haldeman) (Diptera Cecidomyiidae) galling leaves of *Robinia pseudoacacia* L. (Fabaceae) in Italy and Europe. *Frustula entomologica* 25: 117–122.

EPPO (2002) List of biological control agents widely used in the EPPO region. *EPPO Bulletin* 32: 447–461.

EPPO (2004) Occurrence of *Rhagoletis completa* in *Germany*. *EPPO Reporting Service* 9: 2004/133.

EPPO (2006) Distribution maps for quarantine pests. *Liriomyza huidobrensis*

EPPO (2007) First outbreak of *Rhagoletis cingulata* in Slovenia. *EPPO Reporting Service* 8: 2007/148.

EPPO (2008) Dasineura gleditchiae (Diptera: Cecidomyiidae): une espèce envahissante en Europe. *EPPO Reporting Service* 11: 2008/224.

EPPO (2010) First record of *Drosophila suzukii* in Italy: addition to the EPPO Alert List. *EPPO Reporting Service* 1: 2010/007.

Eritja R, Aranda C, Padrós J, Goula M, Lucientes J, Escosa R, Marquès E, Cáceres F (2000) An annotated checklist and bibliography of the mosquitoes of Spain (Diptera: Culicidae). *European Mosquito Bulletin*. 8: 10–18.

Eritja R, Escosa R, Lucientes J, Marques E, Molina R, Roiz D, Ruiz S (2005) Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. *Biological Invasions* 7 (1): 87–97.

Estal P, Soria S, Vinuela E (1998) Nota de la presencia en España de *Dasineura gleditchiae* (Osten Sacken), sobre acacia de tres espinas. *Boletín de Sanidad Vegetal Plagas* 24: 225–230.

Fauna Europaea. http://www.faunaeur.org/.

Felt EP (1914) *Acaroletes pseudococci* n. sp. *Journal of Economic Entomology* 6: 148–149.

Fiedler Z (2005) [A predatory midge *Therodiplosis persicae*, a factor supporting effectiveness of *Phytoseiulus persimilis* (Athias-Henriot) in reduction of *Tetranychus urticae* (Koch) on tomato plants in the greenhouse] (in Polish). *Progress in Plant Protection* 45: 650–654.

Fimiani P (1989) The Mediterranean region. In: Robinson AS, Hooper G (Eds) *Fruit Flies: their Biology, Natural Enemies and Control*. New York: Elsevier, 37–50.

Forsius I (1922) Sammanställning av i Finland hittills anträffade Cecidomyider. *Notulae Entomologicae* 2: 52–57.

Gagné RJ (1972) *Craneiobia lawsonianae* De Meijere, new synonym of *Janetiella siskiyou* Felt (Cecidomyiidae: Diptera). *Proceedings of the Entomological Society of Washington* 74: 128.

Gagné RJ (1989) *The Plant-feeding Gall Midges of North America*. Ithaca, London: Comstock Publishing Associates, Cornell University Press. 356 pp.

Gagné RJ (1994) *The Gall Midges of the Neotropical Region*. Ithaca, London: Comstock Publishing Associates, Cornell University Press. 352 pp.

Gagné RJ (2004) A Catalog of the Cecidomyiidae (Diptera) of the World. *Memoirs of the Entomological Society of Washington* 25: 1–408.

Gatt P, Ebejer MJ (2003) The Ephydridae (Diptera: Brachycera, Muscomorpha) of the Maltese Islands. *Studia Dipterologica* 10: 199–214.

Gederaas L, Salvesen I, Viken Å (Eds) (2007). Norwegian Black List – Ecological Risk Analysis of Alien Species. Artsdatabanken, Norway.

Genduso P (1963) Un Cecidomide dannoso alla Zagara dei limoni, nuovo per la Sicilia e per la fauna mediterranea (*Contarinia citri* Barnes). Bollettino dell'Istituto di Entomologia Agraria di Palermo 31: 65–73.

Georghiou GP (1977) *The insects and mites of Cyprus*. Athens, Greece: Benaki Phytopathological Institute. 347 pp.

Gerson U, Neubaeur I (1976) The citrus blossom midge, *Contarinia citri* Barnes (Diptera: Cecidomyiidae), in Israel. *Phytoparasitica* 4: 163–172.

Gibbs D (1994), *Chymomyza wirthi* Wheeler, 1954 (Drosophilidae) in Essex: a surprising addition to the British list. *Dipterists Digest (Second Series)* 1: 31–33.

Gjaerum HB (1949) Krysantemum-gallmyggen funnet i Norge! *Saertrykk av Gartneryrket* 46: 963–964.

Glavendekić M, Mihajlović L, Petanović R (2007) Introduction and spread of invasive mites and insects in Serbia and Montenegro. In: *Plant protection and plant health in Europe: introduction and spread of invasive species*. BCPC Conference, Humbolt University, Germany, June 2005, 229–230.

Glavendekić M, Roques A, Mihajlović L (2009) An ALARM Case study: The Rapid Colonization of an Introduced Tree, Black Locust by an Invasive North-American Midge and Its Parasitoids. In: Settele J et al. (Eds) *Atlas of Biodiversity Risks - from Europe to the globe, from stories to maps*. Pensoft, Sofia & Moscow (www.pensoftonline.net/alarm-atlas-info, in press.

Grassi A, Palmieri L, Giongo L (2009) *Drosophila (Sophophora) suzukii* (Matsumura). New pest of small fruit crops in Trentino. *Terra Trentina* 10: 19–23.

Gregor F, Rozkošný R (2006) Muscidae Latreille, 1802. In Jedlička L, Stloukalová V, Kúdela M (Eds) Checklist of Diptera of the Czech Republic and Slovakia. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Haenni JP. Personal communication. 14/12/2009 - Häflinger E (1945) Die Chrysanthemum-Gallmücke, ein für die Schweiz neuer Schädling. *Mitt. Biol. Lab. IR Geigy, Basel, Gärtnermeister* 50: 1–7.

Halstead AJ (2004) *Leia arsona* Hutson (Diptera, Mycetophilidae) found again in Britain *Dipterists Digest second series* 11: 98.

Halstead AJ, Harris KM (1990) First British record of a gall midge pest of day lily (*Hemerocallis fulva* L.). *British Journal of Entomology* 3: 1–2.

Harris KM (1976) Cecidomyiidae. In Kloet GS, Hincks WD (Eds) *A check list of British insects. Diptera and Siphonaptera*. London: Royal Entomological Society, 32–42.

Harris KM (2004) New records of Cecidomyiidae (Diptera) in Britain. *Dipterists Digest* 11: 33–40.

Harris KM, Goffau LJW (2003) *Horidiplosis ficifolii*, a new species of gall midge (Diptera" Cecidomyiidae) damaging ornamental fig plants, *Ficus benjamina* L. *Tijdschrift voor Entomologie* 146: 301–306.

Heller K, Menzel F (2006) Sciaridae In Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Hellqvist S (1994). Biology of *Synacra* sp. (Hym., Diapriidae), a parasitoid of *Bradysia paupera* (Dipt., Sciaridae) in Swedish greenhouses. *Journal of Applied Entomology* 117: 491–497.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England*. Peterborough, UK : Report to English Nature N°662.

Houard C (1902) Sur quelques zoocécidies nouvelles ou peu connues, recueillies en France. *Marcellia* 1: 35–49.

Hrubík P (1999) [The first occurrence of the midge *Dasineura gleditchiae* (Diptera: Cecidomyiidae) in Slovakia] (in Slovakian, English abstract). *Entomofauna Carpathica* 11: 6–8.

Irwin AG, Cole JH, Ely WA (2001) *Pelomyia occidentalis* Williston (Dip.:Tethinidae) new to Britain and Germany. *The Entomologist's Record and Journal of Variation* 113 : 153–156.

Ismay J, Smith D (1994) *Prosopantrum flavifrons* (Tonnoir & Malloch) (Diptera, Heleomyzidae) new to Britain and the northern hemisphere. *Dipterists Digest Second Series* 1: 1–5.

Janežič F (1972) Prispevek k poznavanju šišk (zoocecidijev) na rastlinah v Slovenii. I. *Zbornik Biotheniške fakultete Ljubljana* 19: 87–99.

Jones R.A (2004) *Tephritis praecox* (Loew) (Diptera, Tephritidae) established in Britain. *Dipterists Digest second series* 11: 16.

Juhásová G, Hrubík P (1984) *Choroby a škodcovia cudzokrajných drevín na Slovensku*. Bratislava : Veda, Acta Dendrobiologica. 165 pp.

Kabos WJ, van Aartsen B (1984). De Nederlandse boorvliegen (Tephritidae) en prachtvliegen (Otitidae). – Wetenschappelijke Mededelingen van de Koninklijke Nederlandse Natuur historische. *Vereniging* 163: 1–52.

Kahrer A, Skuhravá M (2000) Erstnachweiss von *Feltiella acarisuga* (Vallot, 1827) (Diptera, Cecidomyiidae) in Österreich. *Pflanzenschutzberichte* 59: 49–50.

Kapuscinski S (1948) Nowe dla fauny Polski muchowki i blonkowki szkodniki owoców i nasion drzew i krzewów. *Kosmos Series A* 65: 159–168.

Kieffer JJ (1898) Synopse des Cécidomyies d´Europe et d´Algerie. *Bulletin de la Société d'Histoire Naturelle de Metz* 2: 1–64.

Kieffer JJ, Cecconi G (1906) Un nuovo dittero galligeno su foglie di *Mangifera indica*. *Marcellia* 5: 135–136.

Kinkorová J (2006) *Ceratitis capitata*. In Mlíkovský J, Stýblo P (Eds) *Nepůvodní druhy fauny a flóry České republiky [Alien species in fauna and flora of the Czech Republic]. Praha: ČSOP,* 320.

Klobučar A, Merdić E, Benić N, Baklaić Ž, Krčmar S (2006) First record of *Aedes albopictus* in Croatia. *Journal of the American Mosquito Control Association* 22: 147–148.

Krištal OP (1947) (The signifikance of free-growing vegetation as a food base for multiplication of flies injuring the basic cereal crops) (in Ukrainian). *Zbirnik prac kanivskogo biogeograficeskogo zapovednika* 1: 3–76.

Krištal OP (1959) Cecidomyiidae. In: *Komachi – škidniki silskogospodarskich roslin v umovach lisostepu ta polissja Ukraini*. Kiev: Kievskij Universitet, 83–84.

Kubík Š (2006) Calliphoridae Brauer & Bergenstamm, 1889. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. Available at [http://zoology.fns.uniba.sk/diptera].

Kutter H, Winterhalter W (1933) Untersuchungen über die Erbsenschädlinge im St. Gallischen Rheintale während der Jahre 1931 und 1932. *Landwirtschaftiche Jahrbücher Schweiz* 47: 273–338.

Labanowski G, Soika G (1997) New and lesser known pests occurring on ornamental trees and shrubs. *Progress in Plant Protection* 37: 218–223.

Laguerre M, Dauphin P (2007) Présence en France d´*Obolodiplosis robiniae* (Haldeman) (Diptera, Cecidomyiidae), gallicole sur *Robinia pseudoacacia* L. (Fabaceae). *Bulletin de la Société Linnéenne de. Bordeaux* 142: 291–296.

Lambinon J, Schneider N, Feitz F (2001) Contribution à la connaissance des galles de Diptères (Insecta, Diptera) du Luxembourg. *Bulletin de la Société des Naturalistes luxembourgeois* 1: 51–76.

Lampe I, Burghause F, Krauthausen HJ (2005) Lampe I, Burghause F, Krauthausen HJ (2005) Introduction and distribution of the American Eastern Cherry Fruit Fly, *Rhagoletis cingulata*, in the Rhine

Valley, Germany. *Proceedings of the BCPC Symposium on 'Introduction and spread of invasive species'*, Berlin, June 2005, 135–140.

Langourov M (2004) In: Penev L, Niemela J, Kotze D, Chipev N (Eds) 2004. Ecology of the City of Sofia. Species and Communities in an Urban Environment. Sofia-Moscow: Pensoft.

Lapeyre, Dauphin (2008) Présence en France d' *Exaireta spinigera* (Wiedemann) (Diptera Stratiomyidae). *Bulletin de la Société Linnéenne de. Bordeaux* 143: 257–258.

List of UK Diptera. http://www.eimagesite.net/s1/gst/run.cgi?action=page;p=L65

Loew H (1850) *Dipterologische Beiträge. IV. Die Gallmücken*. Programm K.1850. Friedrich-Wilhelms-Gymnasiums zu Posen Poland. 40 pp.

Löw F (1888) Mitteilungen über neue und bekannte Cecidomyiden. *Verhandllungen der kaiserlich-kongiglichen zoologish-botanischen Gesellschaft in Wien* 38: 231–246.

Máca J (2006) Diptera – Dvoukřídlí. In: Mlíkovský J, Stýblo P (Eds) *Nepůvodní druhy fauny a flóry České republiky [Alien species in fauna and flora of the Czech Republic].* Praha: ČSOP, 317–335.

Máca J (2006) Drosophilidae Rondani, 1856. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Mamaev BM, Krivosheina EP (1965) Ličinki gallic (Diptera, Cecidomyiidae). Moskva: Nauka, 276 pp.

Mamaeva CP (1969) Fauna gallic Moskovskoj oblasti. *Učonye zapiski Moskovskogo ordena trudovogo krasnogo znameni gosudarstvennyj pedagogičeskij institut imeni V.I. Lenina* 362: 37–57.

Mariani M, Beccari F (1964) Prime osservazioni intorno alla presenza di *Contarinia sorghicola* Coquillett in Italia. *Rivista di Agricoltura Subtropicale* e *Tropicale* 58: 362–370.

Martinez M (1982) Contribution à l'étude des Agromyzidae de France (Dipt.) (2ème note). *Liriomyza nietzkei* Spencer et *Liriomyza chinensis* (Kato), deux espèces d"importance économique présentes en France. *Bulletin de la Société entomologique de France* 87: 302–308.

Martinez M, unpublished records.

Martinovic M, Bjegovic P (1949) [Some diseases and pests established in P.R. Serbia in 1949] (in Serbian with English summary). *Zaštita bilja Beograd* 2: 59–68.

Massalongo C (1892) Due nuovi entomocecidii scoperti sulla *Diplachnes serotina* Link. e *Cynodon dactylon* Pers. Dall Doft. *Bullettino della Societa botanica italiana*: 31–33.

Massalongo C (1902) Di un nuovo genere di Ditteri galligeni. *Marcellia* 1: 54–59.

McCrae AWR (1967) Infestation of emulsion paint by the fly *Megaselia scalaris* (Loew) (Dipt., Phoridae). *Entomologist's monthly Magazine* 107: 241–243.

Meijere JCH (1911) Über zwei schädliche Cecidomyiden *Contarinia ribis* Kieff. und *pisicola* n. sp. und über die Erbse bewohnende Dipteren. *Tijdschrift voor Entomologie* 54: 180–194.

Meijere JCH (1935) Über *Craneiobia lawsonianae* de Meij., eine Gallmücke aus den Früchten von *Chamaecyparis lawsoniana* (Dipt. Itonididae).*Tijdschrift voor Entomologie* 78: 129–133.

Meijere JCH (1939) Naamlijst van Nederlandsche Diptera. Tijdschrift Entomologie 82: 137–174.

Mellor PS, Carpenter S, Harrup L, Baylis M, Mertens PPC (2008). Bluetongue in Europe and the Mediterranean Basin: History of occurrence prior to 2006. *Preventive Veterinary Medecine* 87: 4–20.

Mercier L (1927) Présence de *Chrysomyia albiceps* Wied. (Mouche du ver épineux de la laine des moutons australiens) sur la Côte du Calvados. Comptes- rendus Académie des Sciences de France, 795–797.

Merz B (1991) *Rhagoletis completa* and *Rhagoletis indifferens*, two North American fruit-flies of economic importance, new to Europe. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 64, 55–57.

Meyer H, Jaschhof M (1999) Cecidomyiidae, pp.18–32. In: Schumann H, Bährmann R, Stark A (Eds) *Entomofauna Germanica 2. Checkliste der Dipteren Deutschlands*. Studia Dipterologica, Supplement 2, 1–354.

Miller F (1956) *Zemědělská entomologie*. Praha: Nakladatelství Československé akademie věd. 1056 pp.

Miller PL (1979) Intraspecific phorid phoresy. *Entomologist's monthly Magazine* 114: 211–14

Mocek B (2006) Phoridae Latreille, 1796. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera

Moesz G (1938) Magyarország gubacsai. (Die Gallen Ungarns). *Botanikai Közlemenyek* 35: 97–206.

Molliard M (1902) La galle du *Cecidomyia cattleyae* n. sp. *Marcellia* 1: 165–170.

Monclus M (1976) Distribucion y Ecologia de Drosofilidos en Espana II. Especies de Drosophila de la Islas Canarias, con la description de una nueva especie. *Boletín de la Real Sociedad Española de Historia Natural (Biologia)* 74: 197–213.

Natzkova V, Karajova O (1990) Efektivnost na nyakoi preparati spryamo imagoto I larvite na *Liriomyza trifolii* Burg. i *Liriomyza bryoniae* Klalt (Diptera: Agromyzidae). *Plant Science* 7: 96–101.

Neuenschwander P (1984) Erster Nachweis der Olivenfliege *Dacus oleae* (Gmel.) (Dipt. Tephritidae) in der Schweiz. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 57: 286.

Nicoli Aldini R (2005). *Scaptomyza (Parascaptomyza) adusta* (Loew, 1862) (Diptera Drosophilidae). *Bollettino della Societa Entomologica Italiana* 137: 62–63.

Nicoli Aldini R, Baviera C (2002) Note sui ditteri che frequentano le colture di spinacio con segnalazione in Italia del drosofilide nearctico *Scaptomyza adusta* (Loew). Atti XIX Congresso nazionale Italiano Entomologia, Catania, June 2002, 759–763.

Nijveldt W (1965) A new coccid-eating gall midge from Israel. *Entomologische Berichten* 25: 41–43.

Nijveldt W (1980) Niewe galmuggen voor de Nederlandse fauna (VII). *Entomologische Berichten* 40: 53–56.

Pakalniškis S, Bernotienė R, Lutovinovas E, Petrašiūnas A, Podėnas S, Rimšaitė J, Sæther OA, Spungis V (2006) *Checklist of Lithuanian Diptera. New and rare for Lithuania insect species 18*. Vilnius: Lithuanian Entomological Society. 159 pp.

Papp L (1992) Drosophilid assemblages in mountain creek valleys in Hungary (Diptera: Drosophilidae). I *Folia Entomology Hungary* 53: 139–153.

Patsoula E, Samanidou-Voyadjoglou A, Spanakos G, Kremastinou J, Nasioulas G, Vakalis NC (2006) Molecular and morphological characterization of *Aedes albopictus* in northwestern Greece and differentiation from *Aedes cretinus* and *Aedes aegypti*. *Journal of Medical Entomology* 43: 40–54.

Perju T (1959) Contributii la cunoasterea faunei galicole la plantele de cultura din familiile Leguminosae si Cruciferae. *Lucrari stiintifice* 15: 205–210.

Peyrek B (1960) Experiments with *Ceratitis capitata* in Slovensko primorje region in 1959. *Biljna zaštita* 3: 66–70.

Pileckis S, Vengeliauskaite A (1977) [Cecidomyiidae] (in Lithuanian). *Agricultural Entomology* Vilnius, 52–53, 107–108.

Popov A (1995) *Crataerina melbae* (Rond.) neu fur die Balkanhalbinsel (Diptera) Hippoboscidae. *Acta Entomologica Bulgarica* 1: 21–22.

Prell H (1916) Das Springen der Gallmückenlarven. *Zeitschrift für wissenschaftlige Insektenbiologie* 12: 145–148.

Prevosti A (1976) Cariotipo de *Drosophila guanche* Monchls y. *Dettopsomyia nigrovittata* Malloc. *Boletin de la Real Sociedad Espafiola de Historia Natural* 74: 215–217

Purse BV, McCormick BJJ, Mellor PS et al. (2007) Incriminating bluetongue virus vectors with climate envelope models. *Journal of Applied Ecology* 44: 1231–1242.

Ramos HC, Lucientes J, Blasco-Zumeta J, Osácar JJ, Ribeiro H (1998) A new mosquito record for Spain (Diptera: Culicidae). *Abstracts of the XIth European SOVE meeting, Acta Parasitológica Portuguesa* 5, 2.1.

Reiter P (1998) *Aedes albopictus* and the world trade in used tires, 1988–1995: the shape of the things to come? *Journal of the American Mosquito Control Association* 14: 83–94.

Roberti D (1955) I simbionti degli acari fitofagi. I. Therodiplosis persicae Kieffer. Annali della Facoltá di Agraria 51: 66–85.

Roháček J (2006a) *Desmometra microps*; *Trachyopella straminea*; *Pelomyia occidentalis*. In: Mlíkovský J, Stýblo P (Eds) *Nepůvodní druhy fauny a flóry České republiky [Alien species in fauna and flora of the Czech Republic]. Praha: ČSOP,* 321, 334.

Roháček J (2006b) Milichiidae Schiner, 1862. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Roháček J (2006c) Tethinidae Hendel, 1916. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Roháček J (2006d) Ulidiidae Macquart, 1835. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Roháček J, Marshall SA (2000) A world revision of the seaweed fly genus *Thoracochaeta* Duda (Diptera: Sphaeroceridae: Limosininae). Part 2: Palaearctic species. *Studia Dipterologica* 7: 313–372.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Roman N, Ionescu M (1967) Contributiuni la cunoasterea zoocecidiilor din Transilvania. *Contributii botanice Universitatea „Babes Bolyai" din Cluj, Gradina Botanica*: 373–379.

Romi R (1995) History and updating of the spread of *Aedes albopictus* in Italy. *Parassitologia* 37: 99–103.

Romi R, Di Luca M, Majori G (1999) Current status of *Aedes albopictus* and *Aedes atropalpus* in Italy. *Journal of the American Mosquito Control Association* 15: 425–427.

Roques A (1983) *Les insectes ravageurs des cônes et graines de conifères en France*. Versailles : INRA, Service des Publications. 135 pp.

Roques A, unpublished records.

Roskam H, Aa H, As B, Bijkerk J, Ellis W, Moraal L (2008) Massaal voorkomen van *Obolodiplosis robiniae* (Diptera: Cecidomyiidae), een nieuwe galmugsoort voor Nederland. [Explosive occurrence of *robiniae* (Diptera: Cecidomyiidae), a gall midge species new for the Dutch fauna]. *Entomologische Berichten* 68: 27–28.

Rozkošný R (2006) *Hydrotaea aenescens*. In: Mlíkovský J, Stýblo P (Eds) *Nepůvodní druhy fauny a flóry České republiky [Alien species in fauna and flora of the Czech Republic]. Praha: ČSOP.*

Ryberg O (1941) Buxbomsgallmyggan, en för Sverige ny skadegöra. *Växtskyddsuotiser Stockholm* 4: 61–64.

Sabatini A, Raineri V, Trovato G, Coluzzi M (1990) *Aedes albopictus* in Italia e possibile diffusione della specie nellarea del mediterraneo. *Parassitologia*, 32: 301–304.

Saccà G (1964) Nota sulla presenza di *Ophyra aenescens* Wied. (Diptera Muscidae). *Rivista di Parassitologia*, 25: 295–296.

Samanidou A, Harbach RE (2003) *Culex (Culex) tritaeniorhynchus* Giles, a newly discovered potential vector of arboviruses in Greece. *European Mosquito Bulletin* 16: 15–17.

Schaffner F, Angel G, Geoffroy B, Hervy JP, Rhaiem A, Brunhes J (2001) *Les moustiques d' Europe/ The mosquitoes of Europe*. Institut de Recherche pour le Développement, EID Méditerranée. CD-ROM.

Schaffner F, Chouin S, Guilloteau J (2003) First record of *Ochlerotatus (Finlaya) japonicus japonicus* (Theobald, 1901) in metropolitan France. *Journal of the American Mosquito Control Association* 19: 1–5.

Schaffner F, Kaufmann C, Hegglin D, Mathis A (2009) The invasive mosquito *Aedes japonicus* in Central Europe. *Medical and Veterinary Entomology* 23: 448–451.

Schøyen TH (1926) Beretning om skadeinsekter og p1antesygdomme i 1and-og havebruget 1924 og 1925[Report on the noxious insects and plant diseases of the field and the orchard in 1924 and 1925. *Årsberetning off. Foranst. Landbr. Frem*: 8.

Seljak G (2004) [Appearance and incidence of harmful organisms on plants in the Primorska region (Slovenia) in 2003] (in Slovenian). *The annual report to the national Phytosanitary administration of the Republic of Slovenia*: 1–16.

Seljak G, Zežlina I (1999) Appearance and distribution of walnut husk fly (*Rhagoletis completa* Cresson) in Slovenia. *Drustvo za Varstvo Rastlin Slovenije*: 231–238.

Simova-Tošić D, Skuhravá M (1995) The occurrence and biology of Dasineura gleditchiae (Osten Sacken) (Cecidomyiidae, Diptera) in Serbia. *Acta of the Society of Zoology of Bohemia* 59: 121–126.

Simova-Tošić D (2008) Second contribution to knowledge of gall midges (Diptera: Cecidomyiidae) of Serbia. *Bulletin of the Natural History Museum Belgrade* 1: 229–242.

Simova-Tošić D, Skuhravá M, Skuhravý V (1996) Gall midges (Diptera: Cecidomyiidae) of Slovenia. *Scopolia* 36: 1–23.

Simova-Tošić D, Skuhravá M, Skuhravý V (2000) Gall midges (Diptera: Cecidomyiidae) of Serbia. *Acta Entomologica Serbica* 5: 47–93.

Sinacori A, Mineo N (1997) Two new host plants of *Prays citri* and *Contarinia* sp. (?) *citri*. *Informatore Fitopatologico* 47: 13–15.

Siscaro G, Longo S, Lizzio S (1999) Ruolo degli entomofagi di *Aonidiella aurantii* (Maskell) (Homoptera, Diaspidae) in agrumeti siciliani. *Phytophaga Palermo* 9 (Suppl.): 41–52.

Sivell D, Phillips DS (1999) Local Biodiversity Action Plans- Technical Information on Species. III: Invertebrate Animals. *Scottish Natural Heritage Review* 5: 1–104.

Skrzypczynska M, Nijveldt WC, Grijpma P (1993) Differentiation between the larvae of *Resseliella piceae* and *R. skuhravyorum* (Diptera: Cecidomyiidae). *Entomologische Berichte* 53: 176–179.

Skuhravá M (1975) Gallmücken der Slowakei (Cecidomyiidae, Diptera). II. Die Gallmücken der Südwest-, Nordwest- und Ostslowakei. *Biologické Práce* 21: 1–126.

Skuhravá M (1979) Bejlomorky středních Čech (Cecidomyiidae, Diptera). *Bohemia centralis* 8: 125–165.

Skuhravá M (1989) Cecidomyiidae. In Čepelák J (ed) *Diptera Slovenska 3*. Bratislava: Veda, 184.

Skuhravá M (2004) Faunistic records from the Czech and Slovak Republics: Diptera. Cecidomyiidae,. Dipterologica bohemoslovaca, Vol. 11. *Folia Faculty of Sciences Natural University Masaryk Brun Biol* 109: 321–346.

Skuhravá M (2006) *Dasineura gleditchiae*; *Janetiella siskiyou*; *Obolodiplosis robiniae*. In: Mlíkovský J, Stýblo P (Eds) *Nepůvodní druhy fauny a flóry České republiky [Alien species in fauna and flora of the Czech Republic]. Praha: ČSOP,* 320, 330, 333.

Skuhravá M (2008) Cecidomyiidae In: Borges PAV, Abreu C, Aguiar AMF, Carvalho P, Jardim R, Melo I, Oliveira P, Sérgio C, Serrano ARM, Vieira P (Eds) *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos*. Funchal and Angra do Heroísmo: Direcção Regional do Ambiente da Madeira and Universidade dos Açores, 264–265, 329.

Skuhravá M, unpublished records.

Skuhravá M, Skuhravý V (1960) Bejlomorky [Gallmücken]. Praha: ČSAZV. 270 pp.

Skuhravá M, Skuhravý V (2004a) Gall midges (Diptera: Cecidomyiidae) of Cyprus. Dipterologica bohemoslovaca 11. *Folia Faculty of Sciences Natural University Masaryk Brun Biol* 109: 265–283.

Skuhravá M, Skuhravý V (2004b) Bejlomorka akátová – nový invazní druh hmyzu na trnovníku akátu. [*Obolodiplosis robiniae*, a new invasive insect species on *Robinia pseudoacacia*]. *Lesnická práce* 83: 520.

Skuhravá M, Skuhravý V (2009) Gall midges (Diptera: Cecidomyiidae) of Austria. Annotated list of species and zoogeographical analysis. - Gallmücken (Diptera: Cecidomyiidae) von Österreich. Kommentierte Artenlist und zoogeographische Analysis. *Studia Dipterologica* 15 (2008): 49–150.

Skuhravá M, Skuhravý V (in preparation) Gall midges (Diptera: Cecidomyiidae) of Norway.

Skuhravá M, Skuhravý V, Blasco-Zumeta J, Pujade J (2006) Gall midges (Diptera: Cecidomyiidae) of the Iberian Peninsula. 2. Zoogeographical analysis of the gall midge fauna. *Boletín de la Asociación Española de Entomología* 30: 93–159.

Skuhravá M, Skuhravý V, Csóka (2007) The invasive spread of the gall midge *Obolodiplosis robiniae* in Europe. *Cecidology* 22: 84–90.

Skuhravá M, Skuhravý V, Dauphin P, Coutin R (2005) Gall midges of France (Diptera: Cecidomyiidae). *Mémoires de la Société Linnénne de Bordeaux* 5: 1–212.

Skuhravá M, Skuhravý V, Dončev K, Dimitrova BD (1991) Gall midges (Cecidomyiidae, Diptera) of Bulgaria. I. Faunistic researches in the 1978–1987 period. *Acta Zoologica Bulgarica* 42: 3–26.

Skuhrava M, Skuhravy V, Jörgensen J (2006) Gall midges (Diptera: Cecidomyiidae) of Denmark. *Entomologiske Meddelelser* (special issue) 74: 1–94.

Skuhravá M, Skuhravý V, Massa B (2007) Gall midges (Diptera Cecidomyiidae) of Sicily. *Naturalista Siciliano* 31: 261–309.

Skuhravá M, Skuhravý V, Neacsu P (1972) Verbreitung der Gallmücken in Rumänien (Diptera, Cecidomyiidae). *Deutsche Entomologische Zeitschrift* 19: 375–392.

Skuhravá M, Skuhravý V, Skrzypczyńska M, Szadziewski R (2008) Pryszczarki (Cecidomyiidae, Diptera) Polski. [Gall midges (Cecidomyiidae, Diptera) of Poland]. *Annals of the Upper Silesian Museum in Bytom, Entomology* 16: 5–160.

Solinas M (1971) Adattamenti morfologici nel capo delle larve di ditteri Cecidomiidi a regime dietico specializzato. *Atti VIII Congresso Nazionale Italiano di Entomologia*: 70–92.

Spungis V (1977) Faunističeskije materialy po gallicam Latvii. *Latvijas Entomologs* 20: 57–67.

Spungis VV (1988) Dopolnenije k faune gallic (Diptera, Cecidomyiidae) Latvii. *Latvijas Entomologs* 31: 50–57.

Spungis V (2003) A checklist of Latvian Cecidomyiinae (Diptera, Cecidomyiidae) with notes on new records. *Latvijas Entomologs* 40: 5–11.

Starostin SP, Borisenko LA, Silaev AI, (1987) Do not allow yield losses in millet and sorghum. *Zashchita Rastenii (Moscow)* 10: 12–13.

Stelter H (1978) Über neue und weniger bekannte Pflanzengallen. *Archiv der Freunde der Naturgeschichte in Mecklenburg* 18: 69–75.

Steyrer G, Cech TL, Fürst A, Krehan H, Krenmayer W, Kristöfel F, Perny BE, Schaffer H, Stagl WG, Tomiczek C (2002) Forest protection situation 2001 in Austria - surveys and diagnosis of the BFW and documentation of forest damaging factors 2002. *Forstschutz Aktuell* 28. 66 pp.

Stubbs AE, Falk SJ (2002) British Hoverflies an Illustrated Identification Guide. 2nd edition revised and updated by Ball SG, Stubbs AE, McLean IFG, Morris RKA, Falk SJ, Hawkins RD. 469 pp.

Suire J (1935) Sur quelques parasites des chrysanthemes. *Bulletin de la Société d'Histoire Naturelle de l'Herault*, 11 pp.

Šuligoj B (2005) Tigrasti komarji napadajo [Tiger mosquitoes are attacking], Delo, 07.09.2005.

Suma P, Russo A, Longo S (2007) *Horidiplosis ficifolii* (Diptera Cecidomyiidae) infestante su Ficus ornamentali in Sicilia. *Atti XXI Congresso Nazionale Italiano di Entomologia*, Campobasso, June 2007, 230.

Süss L (1991) Prima segnalazione in Italia di *Liriomyza huidobrensis* (Blanchard) (Diptera Agromyzidae). *Bollettino di Zoologia agraria e di Bachicoltura series H* 23: 197–202.

Süss L (2001) *Cerodontha (Poemyza) unisetiorbita* Zlobin (Diptera Agromyzidae) nuova per l'Europa. *Bollettino di Zoologia agraria e di Bachicoltura Series II* 33: 73–77.

Szadziewski R (1991): Cecidomyiidae. In: Razowski J (Ed) *Wykaz zwierzat Polski [Checklist of Animals of Poland]. Vol. 2*. Wroclaw, Warszawa, Krakow: Ossolineum, 122–130.

Szeőke K (2006) [First report about the occurrence of American eastern cherry fruit fly (*Rhagoletis cingulata* Loew.) in Hungary.] (in Hungarian). *Növényvédelem* 42: 470

Taylor MA, Jackson V, Zimmer I, Huntley S, Tomlinson A, Grant R (2006). *Qualitative Veterinary Risk Assessment: Introduction of Exotic Diseases (other than Rabies) in the UK*. Sand Hutton, York: Central Science Laboratory, Veterinary Surveillance Team. 49 pp.

Theobald FV 1911): Report on Economic Zoology for the year ending September 30th, 1911. *The Journal of the South-Eastern Agricultural College Wye, Kent* 20: 89–244.

Theobald FV (1913): Report on Economic Zoology for the Year ending September 30th, 1913. *The Journal of the South-Eastern Agricultural College Wye, Kent* 22: 193–350.

Trent Band H, Bächli G, Neal Band R (2005) Behavioral constancy for interspecies dependency enables Nearctic *Chymomyza amoena* (Loew) (Diptera: Drosophilidae) to spread in orchards and forests in Central and Southern Europe. *Biological Invasions* 7: 509–53.

Trouvé C, Martinez M, Phalip M, Martin C (1991) Un nouveau ravageur en Europe, la mouche mineuse sud-américaine. *Phytoma* 429: 42–46.

Tsacas L, David J, Allemand R, Pasteur G, Chassagnard MT, Derridj S (1977) Biologie évolutive du genre *Zaprionus* recherches sur le complexe spécifique de *Z. tuberculatus* (Dipt. Drosophilidae). *Annales de la Société Entomologique de France (N.S.)* 13: 391–415.

Tullgren A (1917) Skadedjur i Sverige aren 1912–1916. *Meddelanden från centralanstalten för försöksväsendet på jordbruksområdet Stockholm* 152: 1–104.

Urbanelli S, Bellini R, Carrieri M, Sallicandro P, Celli G (2000) Population structure of *Aedes albopictus* Skuse: the mosquito which is colonizing Mediterranean countries. *Heredity* 84: 331–337.

Vacante V, Firullo V (1985) Observations on the population dynamics of *Phytoseiulus persimilis* A. H. (Acarina: Phytoseiidae) on roses in cold greenhouses in the Ragusa Province in Sicily. *Mededelingen Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* 48: 263–271.

Vallot JN (1827) Compte rendu des travaux de l´Académie des Sciences, Arts et Belles-Lettres de Dijon. *Mémoires de l'Académie des Sciences, Arts et Belles-Lettres de Dijon*: 39–112.

Vaňhara J., Tschorsnig HP (2006) Tachinidae Robineau-Desvoidy, 1830. In: Jedlička L, Stloukalová V, Kúdela M (Eds) *Checklist of Diptera of the Czech Republic and Slovakia*. Electronic version 1. http://zoology.fns.uniba.sk/diptera.

Van Rossem G, Burger HC, Bund CF (1976) Schadelijke insekten in 1975. *Entomologische Berichten* 36: 85–87.

Vappula NA (1965) Pests of cultivated plants in Finland. *Annales Agriculturae Fenniae* 19: 1–239.

Venturi F (1956) Notulae dipterologicae. X. Specie nuove per l'Italia. *Bollettino della Società Entomologica Italiana* 86: 56–58.

Vercambre B, Martinez M, Vidal A, Fourrier N, Dufort B, Chanterau J (2000) *Atherigona soccata*, ravageur du sorgho. Première citation de cette mouche en France métropolitaine. *Phytoma- Défense des végétaux* 528: 41–42.

Vimmer A (1931) *Muší rody v Československé republice [Fly genera in the Czech Republic]*. Praha. 379 pp.

Wahlgren E (1944) Cecidiologiskar anteckningar V. *Entomologisk tidskrift* 65: 50–121.

Wahlgren E (1951) Cecidiologiska anteckningar VI. *Entomologisk tidskrift* 72: 84–156.

Wehrmaker A (2007) The black locust gall midge *Obolodiplosis robiniae* (Diptera: Cecidomyiidae) already widespread in southwestern Germany in 2006. *Cecidology* 22: 57–59.

Wermelinger B, Skuhravá M (2007) First record of the gall midge *Obolodiplosis robiniae* (Haldeman) (Diptera: Cecidomyiidae) and its associated parasitoid *Platygaster robiniae* Buhl & Duso (Hymenoptera: Platygastridae) in Switzerland. *Mittelungen der schweizeischen entomologschen Gesellschaft*. 80: 217–221.

White PF, Smith JE, Menzel F (2000). Distribution of Sciaridae (Dipt.) species infesting commercial mushroom farms in Britain. *Entomologist's Monthly Magazine* 136: 207–209.

Whittington AE (2002) *Terellia fuscicornis* (Loew, 1844) (Dipt., Tephritidae) new to Britain. *Entomologist's Monthly Magazine* 138: 119 – 120.

Zúbrik M, Kunca A, Vakula J (2007) Invázne nepovodné druhy hmyzu a húb na Slovensku a ochrana Európského priestoru zabezpecovana "EPPO". In: Kunca A (Ed) *Aktuálne problémy v ochrane lesa*. Zvolen: Národné Lesnícke Centrum, 83–88.

Zwart P, Disney RHL, de Batist P, Mutschmann F (2005) The phorid "scuttle fly" (Megaselia scalaris) a threat to zoological collections and especially to amphibians? *The Bulletin of the British Veterinary Zoological Society* 5: 27–30.

Table 10.1. Diptera species alien *to* Europe. List and characteristics. Status: **A**: Alien *to* Europe; **C**: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Last update 05/02/2010.

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Agromyzidae								
Cerodontha unisetiorbita Zlobin, 1993	A	Phyto-phagous	Asia	2001, IT	AL, IT	I2	Bamboos	Süss (2001)
Liriomyza chinensis Kato, 1949	A	Phyto-phagous	Asia	1982, FR	FR	I1	*Allium* spp.	Martinez (1982)
Liriomyza huidobrensis (Blanchard, 1926)	A	Phyto-phagous	C. & S. America	1989, FR	AL, AT, BE, BG, CH, CY, CZ, ES, ES-CAN, FR, GR, GR-CRE, HU, HR, IL, IT, IT-SIC, MT, NL, PL, NO, PL, PT, RS	I1, I2, J100	Polyphagous leaf miner	Beschovski and Karadjova (1996), Carles-Tolra and Andersen (2002), Cerný (2006), Cerný and Vála (2006), EPPO (2006), Gederaas et al. (red.) (2007), Glavendekić et al. (2007), Roll et al. (2007), Süss (1991), Trouvé et al. (1991)
Liriomyza trifolii (Burgess, 1880)	A	Phyto-phagous	North America	1976, FR	AL, AT, BA, BE, CH, CY, ES, ES-CAN, FR, GR, HR, IT, IT-SAR, IT-SIC, IL, MT, NL, NO, PT, RO, RS, RU	I1	Polyphagous leaf miner	Aguilar & Martínez (1979), Arzone (1979), Carles-Tolra and Andersen (2002), Cerný and Vála (2006), EPPO (2006), Gederaas et al. (red.) (2007), Glavendekić et al. (2007), Máca (2006), Roll et al. (2007)
Phytoliriomyza jacarandae Steyskal & Spencer, 1978	A	Phyto-phagous	South America	2006, IT-SIC	IT-SIC, IT	I2	*Jacaranda mimosifolia*	Bella et al (2007)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Braulidae								
Braula schmitzi Orosi Pal, 1939	C	Parasitic/ Predator	Cryptogenic	1998, GB	BG, ES, FR, GB, GR, IT, PT	E, J	Bees	Carles-Tolra and Andersen (2002), Dobson (1999)
Calliphoridae								
Chrysomyia albiceps (Wiedemann, 1819)	C	Parasitic/ Predator	Cryptogenic	1927, FR	AT, BG, CH, ES, ES-BAL, ES-CAN, FR, HR, MT, PT-MAD, PT-AZO, SK	E	Cadavers	Carles-Tolra and Andersen (2002), Fauna Europaea, Kubík (2006), Mercier (1927)
Canacidae (=Tethinidae)								
Pelomyia occidentalis Williston, 1893	A	?	North America	2001	CZ, DE, HU, PL, SK	U	unknown	Irwin et al. (2001), Roháček (2006a), Roháček (2006c)
Cecidomyiidae								
Asphondylia buddleia Felt, 1935	A	Phyto-phagous	North America	1999, FR	FR	I2	*Buddleia racemosa*	Beguinot (1999), Gagné (1989), Skuhravá et al. (2005)
Clinodiplosis cattleyae (Molliard, 1903)	A	Phyto-phagous	C. & S. America	1885, GB	FR, GB	J, J100	*Cattleia* and other Orchidaceae	Barnes (1948), Gagné (1994), Molliard (1902), Skuhravá et al. (2005)
Contarinia citri Barnes, 1944	A	Phyto-phagous	Africa	1957, CY	AL, CY, IL, IT, IT-SIC	I	*Citrus* spp.	Genduso (1963), Georghiou (1977), Sinacori and Mineo (1997), Skuhravá and Skuhravý (2004a)
Contarinia quinquenotata (F. Löw, 1888)	A	Phyto-phagous	Asia (Temperate)	1885, AT	AT, BG, CZ, DE, F- COR, GB, HU, LV, NL, NO, PL, SE	I2, J6	*Hemerocallis fulva*	Balas (1943), Dittrich (1913), Docters van Leeuwen (1957), Halstead and Harris (1990), Löw (1888), Miller (1956), Prell (1916), Skuhravá (1975), Skuhravá and Skuhravý (in prep.), Skuhravá et al. (1991), Spungis (1988), Wahlgren (1944)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Dasineura gibsoni Felt, 1911	A	Phyto-phagous	North America	1976, GB	GB,	F4, I	*Cirsium*	Gagné (1989), Harris (1976)
Dasineura gleditchiae (Osten Sacken, 1866)	A	Phyto-phagous	North America	1975, NL	AL, AT, BG, CH, CZ, DE, DK, ES, FR, FR-COR, GB, GR,HU, IT, LU, NL, PL, RS, SK	I2	*Gleditchia triacanthos*	Bolchi Serini and Volonté (1985), Dauphin (1991), Dimitrova and Pencheva (2004), Dini-Papanastasi and Skarmoutsos (2001), EPPO (2008), Estal et al. (1998), Halstead (2004), Hrubík (1999), Labanowski and Soika (1997), Lambinon et al. (2001), Meyer and Jaschhof (1999), Nijveldt (1980), Simova-Tošić (2008), Simova-Tošić et al. (2000), Skuhravá (2004), Skuhravá M (Unpublished), Skuhrava et al. (2006), Steyrer et al. (2002)
Dasineura oxycoccana (Smith, 1890)	A	Phyto-phagous	North America	1997, IT	AL, FR, IT, SI	FB	*Vaccinium* spp.	Bosio et al. (1998), Gagné (1989), Seljak (2004)
Dicrodiplosis pseudococci (Felt, 1914)	A	Predator	Africa	1914, IT-SIC	ES, IT-SIC	I	Scale, *Planococcus citri*	Carles-Tolra and Andersen (2002), Felt (1914), Solinas (1971)
Epidiplosis filifera (Nijveldt, 1965)	A	Predator	Eastern Asia	1965, IL	GB, IL, LV, PT-MAD	U	Scale (*Ceratoplates floridensis*)	Harris (2004), Nijveldt (1965), Skuhravá (2008), Skuhravá et al. (2006), Spungis (2003)
Feltiella acarisuga (Vallot, 1827)	C	Predator	Cryptogenic	1827, ?	AL, AT, BE, CH, CZ, DE, DK, ES, FI, FR, GB, IE, IT, IT-SIC, LT, LV, NL, NO, PL, RU, SE	I, J100	Mites (Tetra-nychidae)	EPPO (2002), Fiedler (2005), Kahrer and Skuhravá (2000), Mamaev and Krivosheina (1965), Meijere (1939), Roberti (1955), Skuhrava et al. (2006), Spungis (2003), Vacante and Firullo (1985), Vallot (1827), Vimmer (1931)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Horidiplosis ficifolii Harris, (2003	A	Phyto-phagous	Asia (Tropical)	2001, NL?	DK, GB, IT-SIC, NL	X24	*Ficus benjamina*	Harris and Goffau (2003), Skuhrava et al. (2007), Suma et al. (2007)
Janetiella siskiyou Felt, 1917	A	Phyto-phagous	North America	1931, NL	AL, CZ, DE, DK, FR, GB, IT, NL, PL, SK	I2	*Chamae-cyparis lawsoniana*	Coutin (1976), Gagné (1972), Harris (2004), Juhásová and Hrubík (1984), Kapuscinski (1948), Meijere (1935), Skuhravá (1979), Skuhrava et al. (2006), Stelter (1978)
Lestodiplosis aonidiellae Harris, 1968	A	Predator	Africa	1999, IT-SIC	IT-SIC	J100	Scale (*Aonidiella aurantii*)	Siscaro et al. (1999), Skuhrava et al. (2007)
Obolodiplosis robiniae (Haldeman, 1847)	A	Phyto-phagous	North America	2003, IT	AL, AT, BA, CH, CZ, DE, FR, FR-COR, GB, GR-ION, HR, HU, IT, MK, NL, PL, RS, SI, SK, UA	G, I2, H1	*Robinia pseudoacacia*	Bathon (2007), Berest and Titar (2007), Csóka (2006), Duso C et al. (2005), Duso C and Skuhrava (2003), Glavendekić et al. (2009), Laguerre and Dauphin (2007), Roskam et al. (2008), Simova-Tošić and Skuhravá (1995), Skuhravá M (Unpublished), Skuhravá and Skuhravý (2004b), Skuhravá (2007), Skuhrava et al. (2008), Wehrmaker (2007), Wermelinger and Skuhravá (2007), Zúbrik et al. (2007)
Orseolia cynodontis Kieffer & Massalongo, 1902	A	Phyto-phagous	Africa	1892, IT	FR, HU, IT, RO	E1	*Cynodon dactylon*	Houard (1902), Massalongo (1892), Moesz (1938), Roman and Ionescu (1967), Skuhrava et al. (1972)
Procontarinia matteiana Kieffer & Cecconi, 1906	A	Phyto-phagous	Asia (Tropical)	1906, IT-SIC	IT-SIC	I2	*Mangifera indica*	Kieffer and Cecconi (1906), Skuhrava et al. (2007)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries and islands	Habitat*	Hosts	References
Prodiplosis vaccinii (Felt, 1926)	A	Phyto-phagous	North America	2001, ES	ES	I2	V*accinium* spp.	Calvo et al. (2006), Skuhravá et al. (2006)
Prodiplosis violicola (Coquillett, 1900)	A	Phyto-phagous	North America	2004, NL/SE	NL, SE	I	*Viola* spp.	Gagné (2004)
Resseliella conicola (Foote, 1956)	A	Phyto-phagous	North America	1999, DK	DK	I2	*Picea sitchensis*	Skuhrava et al. (2006)
Rhopalomyia chrysanthemi (Ahlberg, 1939)	A	Phyto-phagous	Asia (Temperate)	1935, FR	BE, CH, DE, DK, FI, FR, GB, NO, PL, SE	X24, I2	*Chrysan-themum* (cultivated)	Barnes (1948), Behr (1949), Blauvelt (1939), Bovien (1935), Gjaerum (1949), Häflinger (1945), Skuhrava et al. (2006), Suire (1935), Szadziewski (1991), Vappula (1965), Wahlgren (1951)
Rhopalomyia grossulariae Felt, 1911	A	Phyto-phagous	North America	1913, GB	GB,	G1	*Ribes grossularia*	Barnes (1948), Theobald (1913)
Stenodiplosis panici Plotnikov, 1926	A	Phyto-phagous	Asia (Temperate)	1926, RU	BG, RS, RU, SI, UA	I	*Panicum* spp.	Dombrovskaja (1936), Janežič (1972), Krištal (1959), Martinovic and Bjegovic (1949), Simova-Tošić et al. (1996), Simova-Tošić et al. (2000), Skuhravá et al. (1991)
Stenodiplosis sorghicola (Coquillett, 1899)	A	Phyto-phagous	Africa	1964, IT	FR, GR, IT, RU	I	*Sorghum* spp.	Coutin (1969), Mariani and Beccari (1964), Skuhravá et al. (2005), Starostin et al. (1987)
Culicidae								
Aedes albopictus (Skuse, 1894)	A	Parasitic/ Predator	Asia (Tropical)	1979, AL	AL, CH, ES, FR, GR, GR-ION, HR, IL, IT, IT-SIC, ME, RS, SI	J6	Humans (biting)	Adhami and Murati (1987), Dalla Pozza and Majori (1992), Eritja et al. (2005), Klobučar et al. (2006), Patsoula et al. (2006), Reiter (1998), Romi (1995), Romi et al. (1999), Sabatini et al. (1990), Šuligoj (2005), Urbanelli et al. (2000)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Aedes japonicus (Theobald, 1901)	A	Parasitic/ Predator	Asia (Temperate)	2000, FR	BE, CH, DE, FR	J6	Humans (biting)	Andreadis et al. (2001), Schaffner et al. (2003), Schaffner et al. (2009)
Culex deserticola Kirkpatrick, 1925	A	Parasitic/ Predator	Africa	1993, ES	ES	C1, D	Wild rabbits	Eritja et al. (2000), Ramos et al. (1998)
Culex tritaeniorhynchus Giles, 1901	A	Parasitic/ Predator	Asia (Tropical)	1987, AL	AL, GR	D6, C1	Humans (biting)	Adhami (1987), Samanidou and Harbach (2003)
Culex vishnui (Theobald, 1901)	A	Parasitic/ Predator	Asia (Tropical)	1987, AL	AL	C1, D	Humans (biting)	Adhami (1987)
Ochleroratus atropalpus (Coquillett, 1902)	A	Parasitic/ Predator	North America	1996, IT	IT	J6	Humans (biting)	Romi et al. (1999)
Ochleroratus subdiversus (Martini, 1926)	A	Parasitic/ Predator	Asia (Temperate)	1987, RS	RS	D	Humans (biting)	Bozicic (1987), Schaffner et al. (2001)
Dolichopodidae								
Micropygus vagans Parent, 1933	A	Parasitic/ Predator	Australasia	1970, IE	GB, IE	G, I2	Broadleaved woodlands	Chandler (2004)
Drosophilidae								
Chymomyza amoena (Loew, 1862)	A	Phyto-phagous, Detri-vorous	North America	1975, CZ	AT, CH, CZ, DE, ES, FR, GB, HU, LT, MO, NL, RO, RS, RU, SK,	G, I2, J1	Apple, fruits, nuts	Clemons (2009), Máca (2006), Máca (2006), Pakalniškis et al. (2006), Trent Band et al. (2005)
Chymomyza procnemis (Williston, 1896)	A	Detri-vorous	North America	2000, ES-CAN	ES-CAN	?	Unknown	Carles-Tolra and Andersen (2002)
Chymomyza procnemoides Wheeler, 1952	A	Detri-vorous	North America	1992, HU	HU	G	Unknown	Band (1994), Perju (1959)
Chymomyza wirthi Wheeler, 1954	A	Detri-vorous	North America	1994, GB	GB	B	Unknown	Gibbs (1994)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Dettopsomyia nigrovittata (Malloch, 1924)	A	Detri-vorous	Tropical Subtropical	<1976, ES-CAN	ES-CAN		Unknown	Carles-Tolra and Andersen (2002), Prevosti (1976)
Drosophila curvispina Watabe & Toda, 1984	A	Detri-vorous	Asia	2002, CH	CH	G	Fungi (forest floor)	Bächli et al. (2002)
Drosophila busckii Coquillett, 1901	C	Detri-vorous	Cryptogenic	1900, GB	CZ, GB, LT, SK	G	Unknown	Hill et al. (2005), Máca (2006), Máca (2006), Pakalniškis et al. (2006)
Drosophila hydei Sturtevant, 1921	C	Detri-vorous	Cryptogenic	1900, GB	CZ, ES, ES-BAL, GB, LT, PT, PT-AZO, PT-MAD, SK	G	Unknown	Carles-Tolra and Andersen (2002), Hill et al. (2005), Máca (2006), Pakalniškis et al. (2006)
Drosophila immigrans Sturtevant, 1921	C	Detri-vorous	Cryptogenic	1900, GB	CZ, ES, ES-CAN, GB, LT, PT, PT-AZO, PT-MAD, SK	G	Fruits	Carles-Tolra and Andersen (2002), Hill et al. (2005), Máca (2006), Pakalniškis et al. (2006)
Drosophila repleta Wollaston, 1858	C	Detri-vorous	Cryptogenic	1900, GB	CZ, ES, ES-BAL, ES-CAN, GB, LT, PT, PT-AZO, PT-MAD, SK	G	Unknown	Carles-Tolra and Andersen (2002), Hill et al. (2005), Máca (2006), Pakalniškis et al. (2006)
Drosophila melanogaster Meigen, 1830	C	Detri-vorous	Cryptogenic	1900, GB	CZ, GB, IT, LT, PT, SK	G	Unknown	Bächli (2004), Hill et al. (2005), Máca (2006), Pakalniškis et al. (2006)
Drosophila suzukii (Matsamura, 1931)	C	Phyto-phagous	Cryptogenic	2009, IT	IT, SP	G	Fruits	EPPO (2010), Grassi et al. (2009)
Drosophila tsigana Burla & Gloor, 1952	C	Detri-vorous	Cryptogenic	?	AT, FR, HU, PT	G	Leaf miner	Fauna Europaea
Scaptomyza adusta (Loew, 1862)	A	Phyto-phagous	North America	1996	IT, GR, MT, ES-CAN, PT-AZO	I, J	Vegetables (Leaf miner)	Nicoli Aldini (2005), Nicoli Aldini and Baviera (2002)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Scaptomyza vittata (Coquillett, 1895)	A	Phyto-phagous	North America	?	GB, SP- CAN	J100, I	Fruits	Carles-Tolra and Andersen (2002), Roll et al. (2007)
Zaprionus ghesquierei Collart, 1937	A	Phyto-phagous	Africa	1991, CY	CY		Fruits	Chassagnard and Kraaijeveld (1991)
Zaprionus indianus Gupta, 1970	A	Phyto-phagous	Africa	1976, ES-CAN	AT, ES-CAN, IL, IT		Fruits	Carles-Tolra and Andersen (2002), Monclus (1976), Roll et al. (2007)
Zaprionus tuberculatus Malloch, 1932	A	Phyto-phagous	Africa	1977, ES-CAN	CY, ES-CAN, IL, MT		Fruits	Carles-Tolra and Andersen (2002), Roll et al. (2007), Tsacas et al. (1977)
Ephydridae								
Elephantinosoma chnumi Becker, 1903	A	Parasitic/ Predator	Africa	2003, MT	MT	B	Shore fly	Gatt and Ebejer (2003)
Placopsidella phaenota Mathis, 1986	A	Parasitic/ Predator	Asia	2003, MT	MT	B	Shore fly	Gatt and Ebejer (2003)
Psilopa fratella (Becker, 1903)	A	Parasitic/ Predator	Africa	2002, ES-CAN	ES-CAN, MT	B	Shore fly	Carles-Tolra and Andersen (2002), Gatt and Ebejer (2003)
Fanniidae								
Fannia pusio (Wiedemann, 1830)	A	Detri-vorous	C. & S. America	?	ES, FR, MT	J	Poultry dung	Carles-Tolra and Andersen (2002)
Heleomyzidae								
Prosopantrum flavifrons Tonnoir & Malloch, 1927	A	Detri-vorous	C. & S. America	1991, GB	GB	J		Ismay and Smith (1994)
Hippoboscidae								
Crataerina melbae (Rondani, 1879)	A	Parasitic/ Predator	Cryptogenic	1990, DE	BG, CH, DE, ES, IT	J	Haemato-phagous on birds	Carles-Tolra and Andersen (2002), Popov (1995)
Milichiidae								
Desmometopa microps Lamb, 1914	A	Parasitic/ Predator	Cryptogenic	?	CZ, SK, HU	J	Adults attack bees	Roháček (2006a), Roháček (2006b)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Desmometopa varipalpis Malloch, 1927	A	Detri-vorous	Cryptogenic	?	FR, G, ES, CH	J	Biofilters, sewage filters, decaying vegetables and fruits	Carles-Tolra and Andersen (2002), Roháček (2006b)
Muscidae								
Athrerigona soccata Rondani, 1871	C	Phyto-phagous	Cryptogenic	1998, FR	FR, GR, HU, IT, IT-SIC,	I1	Sorghum	Vercambre et al.(2000)
Hydrotaea aenescens (Wiedemann, 1830)	A	Parasitic/ Predator	North America	1964, IT	AT, CH, CZ, DE, ES, ES-CAN, FR, GB, IE, IT, IT-SAR, MT, PT, PT-AZO, SK	E, J	Predator of house fly	Carles-Tolra and Andersen (2002), Gregor and Rozkošný (2006), Rozkošný (2006), Saccà (1964)
Mycetophilidae								
Leia arsona Hutson, 1978	A	Detri-vorous	Africa	1978, GB	CH, ES-CAN, GB, MT, NL, PT-AZO, PT-MAD	I, J	Fungus gnat	Carles-Tolra and Andersen (2002), Halstead (2004)
Phoridae								
Chonocephalus depressus Meijere, 1912	A	Detri-vorous	Asia (Temperate)	2002, MT	MT	J	Ripe fruits	Disney (2002)
Chonocephalus heymonsi Stobbe, 1913	A	Detri-vorous	Africa	1981, GB	GB,	J100	Ripe fruits	Disney (1980), Disney (2002)
Dohrniphora cornuta (Bigor in de la Sagra, 1857)	A	Detri-vorous	Australasia	1997	AT, BG, BE, CY, CZ, DE, ES, ES-CAN, FR, GB, NL, PL, PT, PT-AZO, PT-MAD, SI, SK,	J	sapro-phagous	Beschovski and Langourov (1997), Carles-Tolra and Andersen (2002), Disney (1991), Disney (2002), Mocek (2006)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries and islands	Habitat*	Hosts	References
Dohrniphora papuana Brues, 1905	A	Detrivorous	Africa	2004, ES	ES	J6		Disney (2004)
Hypocerides nearcticus (Borgmeier, 1966)	A	Detrivorous	Africa	2004, ES	ES, SE	U		Disney (2004)
Megaselia gregaria (Wood, 1910)	A	Detrivorous	Australasia	2003	CZ, DE, DK, GB, NO, PL, PT, SE, SI, SK	J6, J1	Mushroom house	Carles-Tolra and Andersen (2002), Disney (2002), Mocek (2006)
Megaselia scalaris (Loew, 1866)	A	Detrivorous, facultative predator/ parasite	Tropical, Subtropical	1994, ES	BE, BG, CH, DE, DK, ES, ES-CAN, FR, GB, IT, NL, PT-MAD	J6, J1	Decaying material, cadavers, myasis agent	Bourel et al (2004), Campobasso et al. (2004), Carles-Tolra and Andersen (2002), Dewaele et al. (2000), Disney (1994), Disney (2002), Disney (2008), Haenni Pers. comm. (2009), Langourov (2004), McCrae (1967), Miller (1979), Zwart et al. (2005)
Megaselia tamilnaduensis Disney in Mohan, Mohan & Disney, 1996	A	Detrivorous	Asia (Tropical)	1999, PL	CH, PL	J	Cultivated oyster mushrooms (*Pleurotus*)	Disney and Durska (1999)
Puliciphora borinquenensis Wheeler, 1900	A	Detrivorous	Tropical, Subtropical	1983, GB	GB	J		Disney (1983)
Sciaridae								
Bradysia difformis Frey, 1948	C	Detrivorous	Cryptogenic	1965, GB	ES, ES-CAN, GB, NO, SE, SK	J100, J1	Mushrooms; ornamentals in nurseries	Carles-Tolra and Andersen (2002), Heller and Menzel (2006), Hellqvist (1994), White et al. (2000)
Sphaeroceridae								
Coproica rufifrons Hayashi, 1991	A	Detrivorous	Australasia	?	ES-CAN, MT	U	Animal dung; leaf litter	Carles-Tolra and Andersen (2002)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries and islands	Habitat*	Hosts	References
Thoracochaeta johnsoni (Spuler, 1925)	A	Detri-vorous	North America	1999, GB	GB, IT	B	Seaweed	Roháček and Marshall (2000)
Thoracochaeta seticosta (Spuler, 1925)	A	Detri-vorous	North America	1999, GB	DK, GB, NO, SE	B	Seaweed	Roháček and Marshall (2000)
Trachyopella straminea Roháček & Marshall, 1986	A	Detri-vorous	North America	?	AD, CY, CZ, ES, ES-CAN, GR-CRE, HU, MT, SK	U	Sapro-phagous	Carles-Tolra and Andersen (2002), Roháček (2006a)
Stratiomyidae								
Exaireta spinigera (Wiedemann, 1830)	A	Detri-vorous	Australasia	2008, FR	FR	I	Compost, houses	Lapeyre and Dauphin (2008)
Hermetia illucens (Linnaeus, 1758)	A	Detri-vorous	North America	1936	CH, ES, ES-BAL, ES-CAN, FR, IT, MT, PT	J6	compost heaps, poutry, bee hives; used for control of house flies	Carles-Tolra and Andersen (2002), Venturi (1956)
Tachinidae								
Blepharipa schineri (Mesnil, 1939)	C	Parasitic/ Predator	Cryptogenic	?	AD, CZ, ES, GB, SK	?	Unknown	Carles-Tolra and Andersen (2002), Vaňhara et al. Tschorsnig (2006)
Catharosia pygmaea (Fallén, 1815)	C	Parasitic/ Predator	Cryptogenic	?	AD, ES, GB, PT	?	Unknown	Carles-Tolra and Andersen (2002)
Clytiomya continua (Panzer, 1789)	C	Parasitic/ Predator	Cryptogenic	?	ES, GB	?	Unknown	Carles-Tolra and Andersen (2002)
Phasia barbifrons (Girschner, 1887)	C	Parasitic/ Predator	Cryptogenic	2001, GB	GB	?	Unknown	Clemons (2001)
Leucostoma edentata Kluger, 1978	A	Parasitic/ Predator	Asia	1995, IT	IT	?		Cerretti (2001)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Sturmia bella (Meigen, 1824)	C	Parasitic/ Predator	Cryptogenic	?	ES, GB	I2, E5, FA	Danaid butterflies (*Ideopsis, Parantica*)	Carles-Tolra and Andersen (2002)
Trichopoda pennipes (Fabricius, 1781)	A	Parasitic/ Predator	North America	1989	AL, ES, FR, IT, IT-SIC	I	Squash bug; southern green stinkbug	Carles-Tolra and Andersen (2002), Colazza et al. (1996)
Zeuxia zejana Kolomiets, 1971	A	Parasitic/ Predator	Asia	1995, IT	IT	?	Unknown	Cerretti (2001)
Tephritidae								
Ceratitis capitata (Wiedemann, 1824)	A	Phyto-phagous	Africa	1873, IT	AL, AT, BG, CH, CZ, ES, ES-BAL, ES-CAN, FR, G, IL, IT, IT-SAR, IT-SIC, ME, PT, PT-AZO, PT-MAD, SI, SR	I	Fruits (poly-phagous)	Carles-Tolra and Andersen (2002), Kinkorová (2006), Peyrek (1960)
Rhagoletis cingulata Loew, 1862	A	Phyto-phagous	North America	1993, DE	DE, HU, NL, SI	G, I2	*Prunus* fruits (wild *P. avium, P. padus, P. serotina*)	van Aartsen (2001), EPPO (2007), Lampe et al. (2005), Szeőke (2006)
Rhagoletis completa Cresson, 1929	A	Phyto-phagous	North America	1991, IT	AL, CH, DE, FR, HR, IT, SI	I2	*Juglans* fruits	Duso (1991), EPPO (2004), Merz (1991), Seljak and Žežlina (1999)
Rhagoletis indifferens Curran, 1932	A	Phyto-phagous	North America	1983, CH	CH	I2	*Prunus* fruits (cultivated).	Merz (1991)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Ulidiidae								
Euxesta notata (Wiedemann, 1830)	A	Detri-vorous, Phyto-phagous ?	North America	2009	FR	?	?	Martinez (Unpublished)
Euxesta pechumani Curran, 1938	A	Detri-vorous	North America	1969, FR	BG, CH, ES, FR, SK	E, I	Carrion; dung	Carles-Tolra and Andersen (2002), Delage (1969), Fauna Europaea, Roháček (2006d)

Table 10.2. Diptera species alien *in* Europe. List and characteristics. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Last update 05/02/2010.

Family *Species*	**Regime**	**Native range**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Anthomyiidae						
Strobilomyia infrequens (Ackland, 1965)	Phyto-phagous	Alps	BE, DK, GB, NL	G	*Larix* spp.	Ackland (1965), Roques (Unpublished)
Strobilomyia laricicola (Karl, 1928)	Phyto-phagous	Alps	BE, GB, DK, NL	G	*Larix* spp.	Ackland (1965), Roques (Unpublished)
Strobilomyia melania (Ackland, 1965)	Phyto-phagous	Alps	BE, DK, NL, GB	G	*Larix* spp.	Ackland (1965), Roques (Unpublished)
Cecidomyiidae						
Aphidoletes abietis (Kieffer, 1896)	Predator	Central, South Europe	GB, LV, RU (?)	I, J100	*Adelges abietis* (Adelgidae)	Harris (1976), Mamaev and Krivosheina (1965), Pakalniškis et al. (2006)
Asphondylia borzi (Stefani, 1898)	Phyto-phagous	Medi-terranean	GB	I	*Rhamnus alaternus*	Harris (1976), Hill et al. (2005)
Contarinia lentis Aczél, 1944	Phyto-phagous	Eastern Medi-terranean	BG, CZ, FR, HU, SK	I	*Lens culinaris*	Aczél (1944), Baudyš (1947), Coutin (1965), Skuhravá (1989), Skuhravá et al. (1991)
Contarinia pisi (Loew, 1850)	Phyto-phagous	Western Asia	AL, AT, BE, BG, CH, CZ, DE, DK, FI, FR, GB, HU, LT, LV, NL, NO, PL, RO, RS, RU, SE, SI, UA	I	*Pisum sativum*	Ambrus (1958), Buhr (1939), Forsius (1922), Kieffer (1898), Krištal (1947), Kutter and Winterhalter (1933), Loew (1850), Mamaeva (1969), Meijere (1911), Pakalniškis et al. (2006), Perju (1959), Pileckis and Vengeliauskaite (1977), Schøyen (1926), Simova-Tošić et al. (1996), Simova-Tošić et al. (2000), Skuhravá and Skuhravý (1960), Skuhravá and Skuhravý (2009), Skuhravá et al. (2005), Skuhravá et al. (1991), Skuhrava et al. (2006), Spungis (1977), Theobald (1911), Tullgren (1917)

Family *Species*	Regime	Native range	Invaded countries and islands	Habitat*	Hosts	References
Contarinia pyrivora (Riley, 1886)	Phyto-phagous	Central, eastern Europe, southwest Asia	DK, GB, LV, NO, SE	I	*Pyrus communis*	Harris (1976), Máca (2006), Skuhravá and Skuhravý (in prep.), Skuhrava et al. (2006), Spungis (1977), Wahlgren (1944)
Dasineura abietiperda (Henschel, 1880)	Phyto-phagous	North-east Europe	GB, IT	G3	*Picea abies*	Harris (1976), Hill et al. (2005)
Dasineura kellneri (Henschel, 1875)	Phyto-phagous	Central Europe, Alps, Carpa-thians	GB	G3	*Larix decidua*	Harris (1976), Hill et al. (2005)
Dasineura pyri (Bouché, 1847)	Phyto-phagous	Central, eastern Europe, southwest Asia	DK, FI, GB, NO, SE	I	*Pyrus communis*	Forsius (1922), Harris (1976), Hill et al. (2005), Skuhrava et al. (2006), Wahlgren (1944)
Dasineura rhododendri (Kieffer, 1909)	Phyto-phagous	Central, south Europe, mountains	GB	I	*Rhodo-dendron ferrugineum*	Chandler (Ed) 1 (1998), Harris (1976)
Kaltenbachiola strobi (Winnertz, 1853)	Phyto-phagous	North-east Europe	GB, NL	G3	*Picea abies*	Harris (1976), Hill et al. (2005), Roques (Unpublished)
Monarthropalpus flavus (Schrank, 1776)	Phyto-phagous	Western Asia, southern Europe, Medi-terranean	AT, CH, CZ, DE, GB, HU, NL, PL, RO, SE, UA	I	*Buxus sempervirens*	Ambrus (1958), Docters van Leeuwen (1957), Harris (1976), Meyer and Jaschhof (1999), Ryberg (1941), Skuhravá and Skuhravý (1960), Skuhravá and Skuhravý (2009), Skuhrava et al. (1972), Skuhrava et al. (2008), Wahlgren (1944)
Phyllodiplosis cocciferae (Tavares, 1901)	Phyto-phagous	Medi-terranean	GB	I	*Quercus ilex*	Chandler (Ed) 1 (1998), Harris (1976)

Family *Species*	**Regime**	**Native range**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Resseliella lavandulae (Barnes, 1953)	Phyto-phagous	Medi-terranean	DE	I	*Lavandula angustifolia*	Meyer and Jaschhof (1999)
Resseliella skuhravyorum Skrzypczynska, 1975	Phyto-phagous	Central Europe, Alps, Carpa-thians	BE, DK, GB, NL	G3	*Larix decidua*	Roques (Unpublished), Skrzypczynska et al. (1993), Skuhrava et al. (2006)
Culicidae						
Aedes vexans (Meigen, 1830)	Parasitic/ Predator	Conti-nental Europe	GB	C1, D	Human (biting)	Taylor et al. (2006)
Aedes cinereus (Meigen 1818)	Parasitic/ Predator	Conti-nental Europe	GB	D, J	Human (biting), dog	Taylor et al. (2006)
Culex territans Walker, 1856	Parasitic/ Predator	Eastern Europe	GB	D, J	Human (biting), dog	Taylor et al. (2006)
Culex pipiens molestus L., 1758	Parasitic/ Predator	Conti-nental Europe	GB	D, J	Human (biting), hot-blooded animals	Taylor et al. (2006)
Syrphidae						
Chamaesyrphus caledonicus Collin, 1940	Parasitic/ Predator	Conti-nental Europe	GB	G3	Aphids larval predator (pine forests)	Sivell and Phillips (1999)

Family *Species*	Regime	Native range	Invaded countries and islands	Habitat*	Hosts	References
Dasysyrphus friuliensis (van der Goot, 1960)	Parasitic/ Predator	Conti-nental Europe	GB	G3	Aphid larval predator (spruce forests); Pollinator *Ranunculus* and Umbelli-ferae (Adult)	Stubbs and Falk (2002)
Didea intermedia Loew, 1854	Parasitic/ Predator	Conti-nental Europe	GB	G3	Aphid larval predator (*Schizo-lachnus pineti*; pine forests)	Stubbs and Falk (2002)
Eriozona erratica (Linnaeus, 1758)	Parasitic/ Predator	Conti-nental Europe	GB	G3	Aphid larval predator (forests)	Ball and Morris (2000)
Eriozona syrphoides (FallÚn, 1817)	Parasitic/ Predator	Conti-nental Europe	GB	G3	Aphid larval predator (spruce and pine forests-larva); Pollinator of Hogweed (*Heracleum sphon-dylium*) (adult)	Ball and Morris (2000)

Family *Species*	**Regime**	**Native range**	**Invaded countries and islands**	**Habitat***	**Hosts**	**References**
Merodon equestris (Fabricius, 1794)	Parasitic/ Predator	Continental Europe	GB	I2, G1	Narcissus and bluebell bulbs	Hill et al. (2005)
Parasyrphus malinellus (Collin, 1952)	Parasitic/ Predator	Continental Europe	GB	G3	Aphid larval predator	Ball and Morris (2000)
Tephritidae						
Bactrocera (Daculus) oleae (Rossi, 1790)	Phytophagous	Mediterranean	CH	I	*Olea*	Neuenschwander (1984)
Tephritis praecox (Loew, 1844)	Phytophagous	Continental Europe	GB, NL		*Calendula arvensis* (flower heads)	Jones (2004), Kabos and van Aartsen (1984)
Terellia fuscicornis (Loew, 1844)	Phytophagous	Mediterranean	GB	I2	Artichoke (flower head)	Whittington (2002)

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Lepidoptera
Chapter 11

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Abstract
We provide a comprehensive overview of those Lepidopteran invasions to Europe that result from increasing globalisation and also review expansion of species within Europe. A total of 97 non-native Lepidoptera species (about 1% of the known fauna), in 20 families and 11 superfamilies have established so far in

Europe, of which 30 alone are Pyraloidea. In addition, 88 European species in 25 families have expanded their range within Europe and around 23% of these are of Mediterranean or Balkan origin, invading the north and west. Although a number of these alien species have been in Europe for hundreds of years, 74% have established during the 20th century and arrivals are accelerating, with an average of 1.9 alien Lepidoptera newly established per year between 2000–2007. For 78 aliens with a known area of origin, Asia has contributed 28.9%, Africa (including Macaronesian islands, Canaries, Madeira and Azores) 21.6%, North America 16.5%, Australasia 7.2% and the neotropics just 5.2%. The route for almost all aliens to Europe is via importation of plants or plant products. Most alien Lepidoptera established in Europe are also confined to man-made habitats, with 52.5% occuring in parks and gardens. We highlight four species in particular, *Diaphania perspectalis*, *Cacyreus marshalli*, *Cameraria ohridella* and *Paysandisia archon*, as the most important current economic threats.

Keywords

biological invasion, introduction, pest species, Europe, Lepidoptera, globalisation

11.1 Introduction

Apart from the undoubted impact of climate change, various other facets of human activity, including the increasingly efficient means of transport in the last century, increased trade and globalisation, are having a dramatic effect on the composition of European faunas. Lepidoptera, as a mostly alate and largely phytophagous insect group, are particularly affected, not only by increased transport of the invasive species, but by increased trade in plants and stored plant products. In addition, many species are spreading to hostplants not used in their area of origin.

Lists of naturalized non-native Lepidoptera are already available for a number of European countries (Agassiz 1996a, Essl and Rabitsch 2002, Geiter et al. 2001, Karsholt and Nielsen 1998, Kenis 2005, Šefrová and Laštůvka 2005). In addition, several detailed case studies have been published on the process of invasion to Europe of several non-native Lepidoptera species (Nash et al. 1995, Šefrová 2001, Šefrová 2002a, Šefrová 2002b, Šefrová and Laštůvka 2001, Whitebread 1990). The first list of terrestrial invertebrate species alien to and within Europe included 272 Lepidoptera species, of which 122 were alien to Europe, 139 alien to countries within Europe, and 11 of cryptogenic origin (DAISIE 2008). We substantially revise and update this list here, in the first comprehensive review of known naturalized non-native Lepidoptera known to Europe.

We divided species into two categories:

1. Naturalized exotic species (originating from a continent other than Europe) whose first introduction into Europe appears to be a direct or indirect (deliberate or accidental) result of human activity (Table 11.1). This includes now well known alien lepidoptera such as the Neotropical castniid moth *Paysandisia archon* (Burmeister,

1880) or the South African lycaenid butterfly *Cacyreus marshalli* (Butler, 1898). We also considered in this category species of unknown origin (cryptogenics) such as the leaf-mining moth *Phyllonorycter platani* (Staudinger, 1870). It is worth noting that we also included here species introduced into confined environments like greenhouses which while not apparently spreading of their own accord, have been introduced with their hostplants, with the potential to spread due to horticultural trade. For instance, 11 species of aquatic Pyralidae have been introduced accidentally by man from Asia and North America into Europe, mostly as contaminants of plants. Current climate makes their establishment in the wild unlikely, but global warming could allow their establishment in the near future.

2. European species spreading throughout the continent as a result of human activity (Table 11.2). This category includes the invasive leaf-mining moth *Cameraria ohridella* Deschka and Dimić, 1986, now understood to be Balkan in origin (Valade et al. 2009). It is worth noticing that although many aliens are highly invasive our review also includes naturalised aliens that are not necessarily invasive such as the saturniid moth *Samia cynthia* (Drury, 1773).

We excluded all the following cases, here giving examples:

i) Species showing clear range expansions/contractions at a country level, which are known to follow global climate change trends (Warren et al. 2001). The butterfly *Colotis evagore* (Klug, 1829) in Spain (Fric, 2005), the processionary pine moth *Thaumetopoea pityocampa* (Denis & Schiffermüller, 1775), in central Europe (Battisti et al. 2005) and several British butterfly species (Asher et al. 2001) are classical examples of this phenomenon. However, it must be noted that *T. pityocampa* has apparently been introduced through human activity from continental Italy to Sardinia (Luciano et al. 2007).

ii) Naturally-expanding species known as migrants which have established without clear human assistance, such as the choreutid *Tebenna micalis* (Mann, 1857) in Azores (Karsholt and Vieira 2005) and the geometrid *Peribatodes secundaria* (Denis & Schiffermüller, 1775) in Great Britain (Kimber, 2008) as well as rare vagrants that may or may not sporadically naturalize, such as *Acontia crocata* Guenée, 1852 in France (Letellier, 2004); *Pardasena virgulana* (Mabille, 1880) in Great Britain (Honey, 1994) and *Gelechia sabinellus* (Zeller, 1839), *Eccopsis effractella* Zeller, 1848 and *Zophodia grossulariella* (Hübner, 1809), all recently recorded from Great Britain (Agassiz 1978a, Agassiz 1996b, Roche 1982).

iii) New records of species probably overlooked in particular countries for which there is no clear evidence of range expansion. For instance, in Great Britain the presence of *Bucculatrix ulmifoliae* Hering, 1931 and *Ocnerostoma* spp. (Heath and Emmet 1996, Langmaid et al. 2007).

iv) Deliberate translocations of species between European countries, such as the introduction of the butterflies *Araschnia levana* (Linnaeus, 1758) (Frohawk, 1940), *Ma-*

culinea arion (Linnaeus, 1758) (Thomas et al. 2009) and *Lycaena dispar* (Haworth, 1803) (Ford, 1945) into Great Britain. These translocations result from solitary enthusiasts or are for conservation management purposes including the reintroduction of extinct species, but have nothing to do with our subject of biological invasion, essentially the aspects associated with increased globalisation.

v) Species once apparently established but now extinct (e.g. in Great Britain, the blastobasid *Blastobasis phycidella* (Zeller, 1839) and the oecophorid *Euclemensia woodiella* (Curtis, 1830) (Emmet 1988, Koster and Sinev 2003)

vi) The large number of living display species (this is the case of butterfly houses), unless these species are either establishing in the wild, or there is evidence they have become greenhouse pests (we have no examples). Nevertheless, we highlight the risks involved in importation of butterflies for butterfly houses and for a new practice of wedding releases.

Finally, the introduction of exotic host plants by man has indirectly allowed several lepidopteran species to expand their distribution range. We consider as alien species *Stigmella speciosa* Frey, 1857*, Caloptilia rufipennella* (Hübner, 1796) and *Phyllonorycter geniculella* (Ragonot, 1874), all feeding on *Acer pseudoplatanus* in northern Europe; *Stigmella suberivora* (Stainton, 1869) feeding on *Quercus ilex* in Great Britain; *Eupithecia phoeniceata* (Rambur, 1834) feeding on *Juniperus* and various Cupressaceae in Belgium and Great Britain, *Cydia grunertiana* (Ratzeburg, 1868) in Belgium, Denmark and Sweden*; C. illutana* (Maslov, 1988) and *C. pactolana* (Zeller, 1840) feeding on *Larix*, the last two in Great Britain; *Thera cupressata* (Geyer, 1831), feeding on imported *Abies* in Sweden and Cupressaceae in Great Britain, and *Lithophane leautieri* (Boisduval, 1829) on Cupressaceae cultivars in Great Britain. *Polychrysia moneta* (Fabricius, 1787) started to spread as early as 1891 in Europe, possibly as a result of rise in popularity of ornamental hostplants such as *Delphinium* in gardens (Agassiz, 1996a). Other well known examples of species which have followed the invasion of their host plants are the milkweed butterflies, *Danaus plexippus* (Linnaeus, 1758) and *Danaus chrysippus* (Linnaeus, 1758). The larvae of both species feed on ornamental and invasive milkweeds (Apocynaceae) which have been introduced in some Macaronesian islands and the Iberian Peninsula (Baez, 1998).

We summarise the relative importance of naturalized alien invasives by family, in relation to their proportion in the relatively well known European fauna, finding great disparities in their prevalence.

11. 2 Diversity of alien lepidopteran species

Lepidoptera is one of the largest insect orders, with around 175,000 described species in 128 families and 47 superfamilies (Kristensen and Skalski 1999, Mallet 2007). About 9,428 native species in 83 families and 31 superfamilies have been recorded in

Europe (Karsholt and Kristensen 2003). A total of 97 non-native Lepidoptera species, in 20 families and 11 superfamilies have established so far in Europe (Table 11.1). Our analysis reveals that there is a significant correlation between the number of alien species and the number of native species per family (Spearman's rho correlation: r= 0.48, P < 0.001). In addition, 88 European species in 25 families have expanded their range within Europe and many of these are of Mediterranean origin, invading northern and western areas of Europe (Table 11.2).

The 20 families which contain alien species to Europe are: Pyralidae (30 species), Tortricidae (10), Gracillariidae (8), Tineidae (7), Noctuidae (6), Gelechiidae (6), Blastobasidae (5), Yponomeutidae (4), Oecophoridae (4), Cosmopterigidae (3), Saturniidae (3), Pterophoridae (2), Nymphalidae (2) and Bucculatricidae, Agonoxenidae, Lycaenidae, Geometridae, Arctiidae, Nolidae and the alien family Castniidae, each with one species (Table 11.1).

Agonoxenidae: Sixteen species of agonoxenids are native to Europe. The Asian species *Haplochrois theae* (Kusnezov, 1916) represents the only alien. During the 20th century this was a serious pest on tea plantations in Georgia and to a lesser degree, in the Krasnodar Territory of Russia (Sinev, 1994).

Arctiidae: One hundred and one species of arctids are native to Europe but only one species, the North American Fall Webworm, *Hyphantria cunea* (Drury, 1773), is alien to the region. The larvae are highly polyphagous, feeding on hundreds of different species of deciduous trees on which they form conspicuous webbed nests in late summer and autumn.

Blastobasidae: Only 41 species of native blastobasid moths have been recorded in Europe, a large evolutionary radiation of which 26 species occur in Madeira (Karsholt and Sinev 2004). However, the number of alien species in this family (five) is relatively high, mainly because the larvae feed usually on dead organic matter. Some species, such as *Blastobasis lacticolella* (Rebel, 1940) are pests of stored foodstuffs. Interestingly, all alien Blastobasidae appear to have colonized continental Europe (mostly Great Britain and/or mainland Portugal) from Madeira, presumably with the import of ornamental plants. The common species *B. adustella* Walsingham, 1894 (originally described as a form of *B. lignea* Walsingham) (Sinev, 2007) is another example. However, *B. adustella* has widely been treated, erroneously, as a synonym of the Madeira endemic species *B. vittata* Wollaston, 1858. Although there are records attributed to *B. vittata* on the internet, including from the British Isles, there are no unambigously identified instances of the introduction of this species outside Madeira at present.

Bucculatricidae: There are 53 native bucculatricids known in Europe. One macaronesian species, *Bucculatrix chrysanthemella* (Rebel, 1896), was recently introduced from the Canaries into Italy and France, where it seems to have established populations. This species has also recently been recorded from Finland, at which latitudes it seems unlikely to become established (Siloaho, 2008). *B. chrysanthemella* attacks Paris Daisy (*Argyranthemum frutescens*), an economically important ornamental crop in some parts of Europe.

Castniidae: This family has no native species in Europe. The majority of castniid moths are Neotropical, while some species are also found in Australia and South-east

Asia. The Neotropical *Paysandisia archon* is the only alien castniid known to occur in Europe and is currently spreading along the Mediterranean coast attacking a wide range of palm species. The castniid *Riechia acraeoides* (Guérin-Méneville, 1832) is one of numerous sporadic adventatives included in the previous list (DAISIE 2008) that we discount here.

Cosmopterigidae: There are 79 species of cosmopterigids native to Europe, with three species considered as aliens. Two of these are African species that feed on *Acacia* in Malta. The larvae feed internally on the leaves, seeds and stems of their hostplants. There is no evidence that *Cosmopterix pulchrimella* Chambers, 1875, recently established in Cornwall, Great Britain, arrived there directly through human agency.

Gelechiidae: There are 697 species of gelechiids known to occur in Europe. The larvae of most species are concealed feeders on plant tissues, many of them feeding internally in seed heads and fruits, some mining and even producing galls. Six alien gelechiids are known from Europe, among them major agricultural pests such as the Tomato Leafminer *Tuta absoluta* (Meyrick, 1917), the cosmopolitan Angoumois Grain Moth *Sitotroga cerealella* (Olivier, 1789), which attacks stored whole cereal grains, and the Pink Bollworm *Pectinophora gossypiella* (Saunders, 1844), whose larvae bore into the flowers and seeds of cotton.

Geometridae: There are 1,024 species of geometrids native to Europe, but only one non-native species appears to have naturalized in Europe. This is *Pseudocoremia suavis* (Butler, 1879), an endemic geometrid to New Zealand (Berndt et al. 2004), which was recorded on five separate occasions in Cornwall in 2007 (James 2008, Skinner 2009), suggesting establishment in the wild. This species, polyphagous on various gymnosperms, represents a potential risk to European conifer forests.

Gracillariidae: There are 249 species of native gracillariids known in Europe and eight alien species have been recorded. Among these are pests of economic importance, such as the Citrus Leafminer *Phyllocnistis citrella* Stainton, 1856.

Lycaenidae: One hundred and thirty-six species of lycaenids are native to Europe. The South African Cacyreus marshalli is one of the few butterflies which are naturalised aliens in Europe (see also under Nymphalidae). This is a pest of cultivated *Pelargonium* plants, mainly in Mediterranean region but it was found to be breeding in Great Britain in 1997 (Lewes, East Sussex), where it became temporally established in greenhouses until May 1998 but was eradicated (Holloway, 1998).

Noctuidae: This is the most species-rich family of Lepidoptera in Europe, with over 1,435 native species. Six alien noctuids have been recorded so far, including some major agricultural pests such as *Chrysodeixis eriosoma* (Doubleday, 1843) and *Spodoptera litura* (Linnaeus, 1758). However, on a cautionary note, these genera are known to have strong migratory tendencies. Indeed we may never know, due to lack of sufficient historical records, when or whether certain noctuids arrived as invasives to Europe or by artificial agency. One good example of this is *Araeopteron ecphaea* (Hampson, 1914) (type locality Nigeria). It is also interesting to note the African and Austral-Oriental fern-feeding species *Callopistria maillardi* (Guenée, 1862) seems to have been accidentally imported with *Nephrolepis* ornamental ferns, but this species has five subspecies and the precise origin of the introduced individuals is unknown. Some records of *Chrysodeixis acuta* (Walker, 1858) could also represent misidentifications of *C. chalcites* (Esper, 1789). Following our exclusion criteria, we have not included singleton records, for example of *Acontia crocata* Guenée, 1852, a specimen of which was collected in Irais (Deux-Sevres), France (Letellier, 2004), possibly resulting passively from a plant import from SE Asia (Hacker et al. 2008).

Nolidae: Thirty-five species of nolids are native to Europe, but only one exotic species has repeatedly been recorded within the region, the Spotted Bollworm, *Earias vittella* (Fabricius, 1794). The larva of this species feeds on several plants of the family Malvaceae, in particular Okra (*Abelmoschus esculentus*) pods, *Gossypium* (it is one of the most important pests of cotton) and *Hibiscus*. It has been found as a vagrant in Great Britain and seems to also be present in southern Spain (Nash, 2003). Its establishment needs to be confirmed.

Nymphalidae: There are 239 species of nymphalid butterflies native to Europe. Two non-native danaine species, the Monarch butterfly *Danaus plexippus* and the Plain Tiger *D. chrysippus* have established themselves in the Macaronesian islands and Iberian Peninsula. We have included both species despite them being well known migrants because their introduction and establishment in Europe has followed the invasion and establishment in Europe of their Apocynaceae host plants (*Asclepias curassavica*, of Neotropical origin and *Gomphocarpus fruticosus* of Afrotropical origin). Thus, the Monarch's range has greatly expanded during the 19th and 20th centuries from North America and now encompasses numerous Atlantic, Pacific and Indian Ocean islands and Australia. A number of hypotheses have been developed to explain this great range expansion (Vane-Wright 1993).

Oecophoridae: There are 120 native species of oecophorids in Europe. Only four alien oecophorids are established in the region, three of which feed on dead plant material.

Pterophoridae: There are 166 native pterophorids known to Europe. Two species, *Megalorhipida leucodactylus* (Fabricius, 1794) and *Lantanophaga pusillidactylus* (Walker, 1864) are known to be alien to Europe. *M. leucodactylus* has a circum-tropical distribution and has established populations in Sicily (Bella and Ferrauo 2005) and Israel. It has also been recorded in Spain, but its presence there needs confirmation (Gielis, pers. comm.). The larvae feed on Amaranthaceae, Cucurbitaceae, Goodeniaceae, Leguminosae, Nyctaginaceae, Rosaceae and Asteraceae (Vargas, 2007). The Lantana Plume Moth *L. pusillidactylus* is also a pantropical species whose origin, as for *M. leucodactylus,* is not clear. This species has been introduced with its Verbenaceae hostplant (which is of neotropical origin), *Lantana camara*, into Spain, Portugal and southern Italy (Aguiar and Karsholt 2006, Bella and Marchese 2007, King 2000). The moth is used as the biocontrol agent against this plant, itself an invasive in many parts of the world.

Pyraloidea (Pyralidae and Crambidae): This superfamily has 898 native species known in Europe. Pyraloidea also has the highest number of species (30) alien to Europe. This is probably due to the high number of alien crambid pyrales that have larvae feeding on submerged and floating aquatic plants used in aquariums and ponds (11 species) as well as cosmopolitan pests that feed on stored products (seven species). These invasives include the North American wax moth *Vitula edmandsii* (Packard, 1865), whose larvae damage the combs of honeybee and bumblebee nests.

Saturniidae: Seven saturniids are native to Europe. Three Asian species have deliberately been introduced into Europe for silk production, but have naturalized from escapes. This family is also very popular among amateur breeders and sometimes there are reports of adult moths of a wide number of species in urban areas.

Tineidae: There are 262 species of native tineids in Europe and seven alien species have also been recorded to the region. At least five of these feed on stored products, cloths, and detritus, such as the Common Clothes Moth (*Tineola bisselliella* (Hummel, 1823)), whose larvae feed on clothing and natural fibres.

Tortricidae: About 977 species of tortrix moths have been recorded as native to Europe. Among the 10 alien species recorded to Europe, there are some economically important pests, in particular of apple trees, for example the oriental fruit moth (*Grapholita molesta* (Busck, 1916)) and the light brown apple moth *Epiphyas postvittana* (Walker, 1863). Larvae of the latter species are not easily distinguished from the larvae of other tortricid leafrollers; only DNA-based testing appears to work reliably for identification. Interestingly, half of the tortricids recorded as alien to Europe (five out of 10 species) are specialists on *Cedrus* and have been introduced into southern France, where plantations of these trees are common.

Yponomeutidae: There are 113 species of ermine moths native to Europe, with four alien species having been recorded. The larvae tend to form communal webs, and some species are agricultural forestry pests, such as the Arborvitae Leafminer, *Argyresthia thuiella* (Packard, 1871) and *Prays citri* (Millière, 1873), a well-known *Citrus* pest in the Mediterranean region. Two North American leafminers of the genus *Argyresthia* attack Cupressaceae in Europe.

In our analysis, it is interesting that we found a similar number of alien species to Europe (Table 11.1) as species that have expanded their range within Europe due to human activity (Table 11.2). Indeed, there is a significant correlation between the number of alien species per family to Europe and the number of alien species per family within Europe (Spearman's rho correlation: r= 0.39, P = 0.044). However, several families exhibit some species which have expanded their range within Europe, yet have very few or no recorded aliens to Europe. For instance, strikingly, Geometridae features only one species alien to Europe within a fauna of 1,024 species, a number of which are known migrants, whereas as many as 11 species have been recorded invading other countries within Europe (Table 11.2). The North American sterrhine geometrid *Idaea bonifata* (Hulst, 1887) has been intercepted several times with imports of dried plant material but, as far as known, is not yet established in Europe (Martinez and Coutin 1985).

The absence of alien species within other species-rich families, such as Coleophoridae (533 spp.), Nymphalidae (239 spp.), Psychidae (231 spp.) Nepticulidae (242 spp.) and Sphingidae (39 spp.) is also notable. In spite of the known high mobility of the last family, several exotic species (i.e. the American *Sphinx drupiferarum* Smith, 1797, *Agrius cingulatus* (Fabricius, 1775) and the African *Polyptychus trisecta* (Aurivillius, 1901)) have been recorded (sometimes repeatedly) within the region, with no confirmed establishment (Marabuto 2006, Pittaway 1993, Waring et al. 2003).

11.3 Temporal trends

The precise date of arrival is not known for two species. An analysis of the 95 species for which the date of the first record in Europe is known shows that the arrival of alien Lepidoptera has dramatically accelerated during the second half of the 20th century (Figure 11.2). This trend is still increasing, with an average of 1.9 alien Lepidoptera newly established per year in Europe between 2000 and 2007 (Figure 11.2). This average is twice that during the period 1975 to 1999 (1.1 species per year). The same trend has been observed for all groups of alien terrestrial invertebrates analysed together (Roques et al. 2008). This temporal trend might be due to the acceleration of processes that happened in much wider time frames in the past, such as global climate change and human assisted transportation via the much faster and more efficient means of transport nowadays.

Alien species have historically been introduced for centuries, so it should not be considered that invasive species are necessarily a 20th century phenomenon, although the poor documention of older cases inevitably also provides more scope for speculation. One such case is *Euclemensia woodiella*, belonging to a North American oecophorid lineage (Koster and Sinev 2003) found in numbers near Manchester in 1829 and not since. A much older potential example is the lasiocampid *Pachypasa otus* (Drury, 1773) with a scattered distribution in southern Italy, whose larva feeds mainly on *Cupressus*, could even have been introduced by the Romans for "Coan" silk production, as it possibly represents the "Assyrian Bombyx" mentioned in Naturalis Historia by Plinus (Good, 1995).

11.4 Biogeographic patterns

For at least 19 alien species, the precise area of origin is not known and these we consider as cryptogenic. We have classified *Phyllonoryctyer platani* (Gracillariidae) as cryptogenic because there are some doubts regarding its origin (Šefrová, 2001). Thus, *P. platani* is either of North American origin and was introduced to Europe with American *Platanus occidentalis,* or it originated in Southeastern Europe and Southwestern and Central Asia, on *Platanus orientalis*. We have included *C. ohridella* as alien within Europe (Table 11.2) since recent genetic studies suggest a Balkan origin as most likely (Valade et al. 2009).

An analysis of the 78 alien species for which the native area of origin is known, shows that Asia has contributed the most alien species with 28.9% (28 out of 97 species) (Figure 11.3). Africa (including Macaronesian islands, Canaries, Madeira and Azores) supplied 21.6% of alien species (21 out of 97 species) followed by North America with 16.5%, Australasia with 7.2%, and the Neotropics, surprisingly few with 5.2%.

Large differences exist among European countries in the number of alien Lepidoptera recorded per country (Figure 11.4). With 42 species, the United Kingdom is the

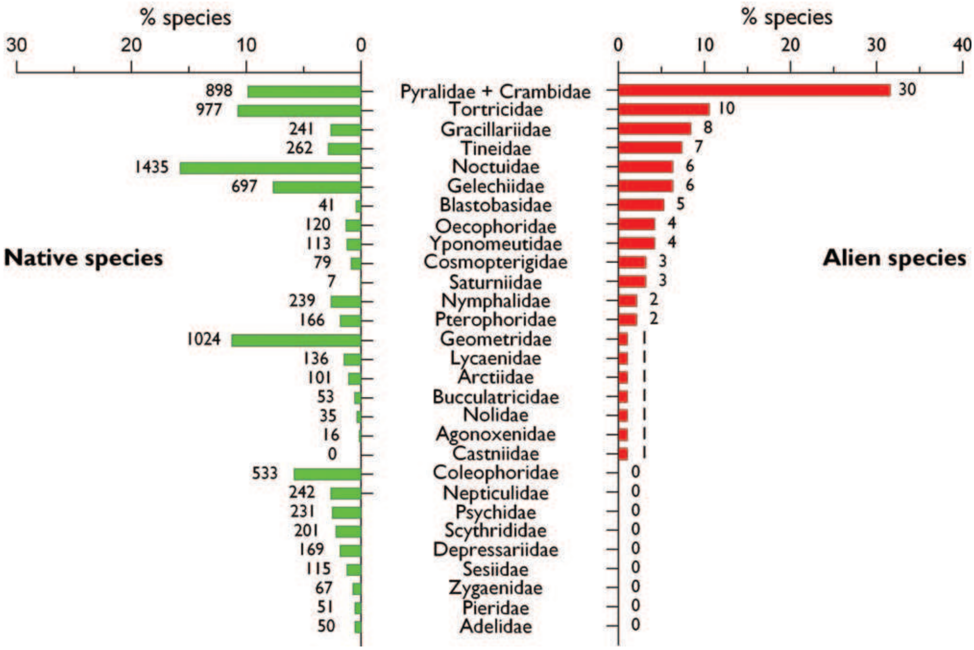

Figure 11.1. Comparison of the number of species per family of Lepidoptera in the alien and native entomofauna in Europe. Families are presented in a decreasing order based on the number of alien species. Only the most important families of native species (> 50 spp.) have been considered.

European country with the highest number of alien Lepidoptera, followed by France (mainland) with 41 and Spain (mainland) with 39 species. Both Moldavia and Luxemburg are the European countries with the lowest number (with one alien species each). These differences are very likely to result at least partly from variation in sampling effort and the availability of local taxonomic expertise, but the area and the geographical location of a country is also a very important factor, in this respect.

11.5 Main pathways and vectors to Europe

As far as we know, most Lepidoptera alien to Europe have been introduced accidentally (96.9%). A clear exception is some saturniid species that were imported from Asia into Europe for silk production in the nineteenth century, and subsequently became naturalized, including in urban areas. On the other hand, the Silkmoth *Bombyx mori* Linnaeus, 1758. has not been included in the analysis, because although it is widespread in captivity throughout Europe, its flightlessness has prevented naturalisation.

The import of ornamental plants (particularly palms, geraniums and azaleas) is most likely responsible for the introduction of several species such as *Paysandisia archon, Cacyreus marshalli* and *Caloptilia azaleella*. Transport also plays an important role in the dispersal of some species, including ones alien within Europe. For instance, *Cameraria*

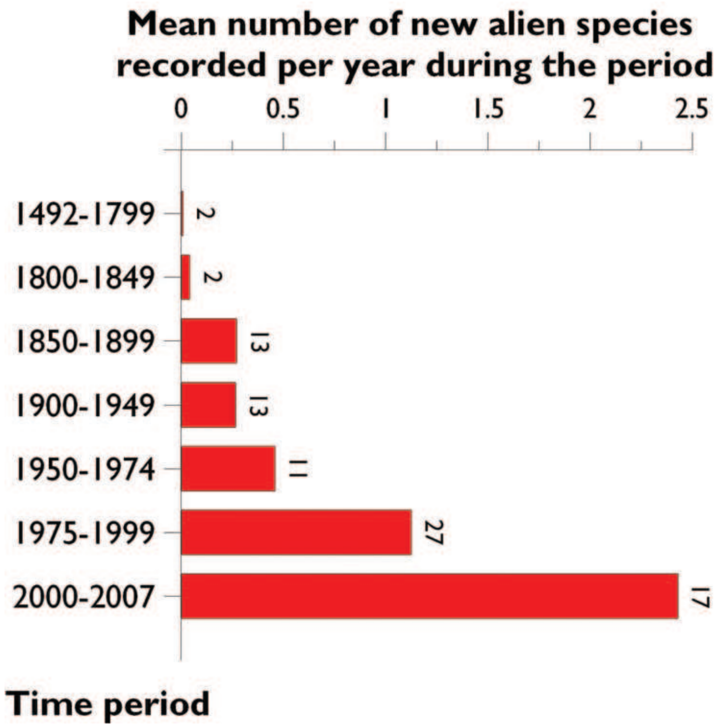

Figure 11.2. Rate of established alien Lepidoptera in Europe since 1492 as mean number of alien Lepidoptera recorded per year. Calculations are made on 95 alien species for which the first record is precisely known. Numbers above bars indicate number of new species recorded per period.

ohridella seems to feed almost exclusively on *Aesculus hippocastanum* trees planted in urban areas and parks. The main means of its spread is likely to be wind dispersal, but human assisted transportation played a major role in the long distance dispersal of this species (Gilbert et al. 2004). Since the advent of tropical butterfly houses in the 1980s, a potential new threat has emerged, the use of mass butterfly releases for weddings, a practice increasingly popular in countries such as Italy, where one of us (AZ) has recorded a number of exotic species flying freely in cities. Usually Monarch butterflies are used, but less scrupulous companies may be using a range of exotics, many of which are likely to find climate change and the availability of hostplants for some papilionid butterflies, such as Rutaceae planted in city gardens propitious for establishment of at least temporary populations.

11.6 Most invaded ecosystems and habitats

Most alien Lepidoptera are phytophagous (78.3%), whereas detritivores represent only 21.6% (Table 11.1). The majority of alien Lepidoptera established in Europe are confined to man-made habitats, and only a few species have become established in a more or less natural environment, mostly in woodlands. Examples of the latter include the

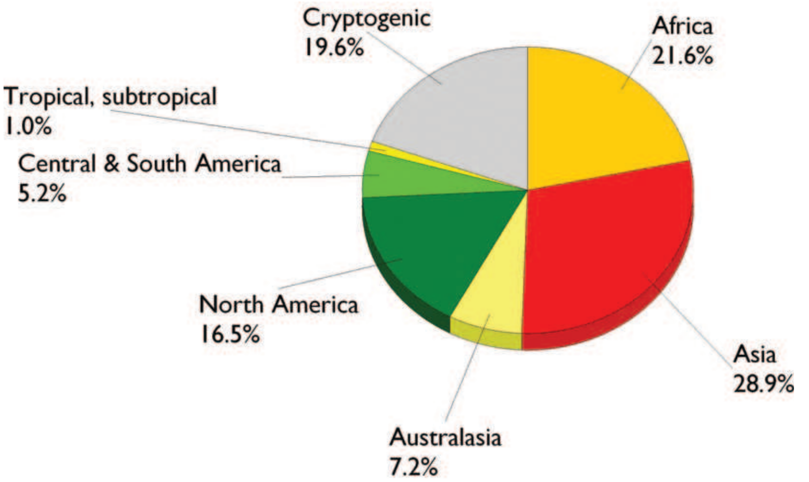

Figure 11.3. Regions of origin of the Lepidoptera species alien *to* Europe

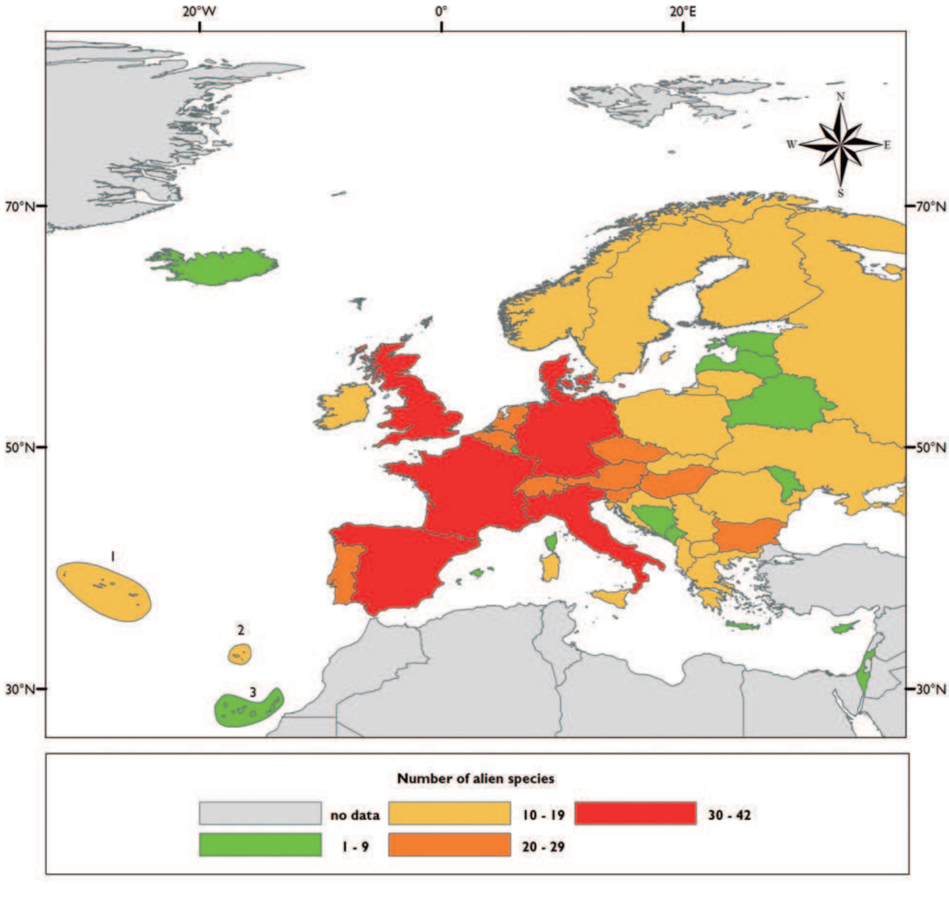

Figure 11.4. Colonization of continental European countries and main European islands by Lepidoptera species alien *to* Europe.

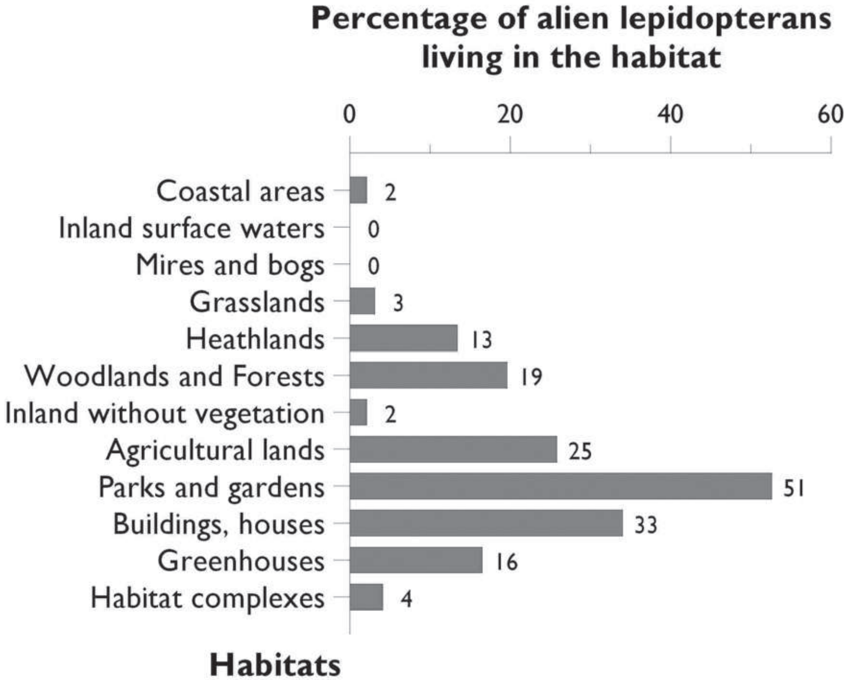

Figure 11.5. Main habitats of 97 alien Lepidoptera species established in Europe (note that a species may live in several habitats).

arctiid *Hyphantria cunea*, the gracillariid *Phyllonorycter issikii* in Central Europe and the saturniid *Antheraea yamamai* in the Balkans.

In Europe, most alien Lepidoptera species feed on their original hostplants. However, some species seem to have been able to switch to other hostplants that are often closely related. For instance, *Paysandisia archon* specializes on *Trithrinax campestris* (Arecaceae) and to a lesser extent on *Cocos yalai* in its native area (Argentina, Uruguay).

However, in Europe this moth has expanded its host range to many ornamental exotic palms (*Phoenix canariensis, Latania* sp.) as well as posing a threat to the native *Chamaerops humilis* (Montagud Alario 2004).

About 50.5% of alien Lepidoptera live indoors in domestic, industrial and other artificial habitats such as 16.5% in greenhouses (Figure 11.5). Six out of the nine species that feed on stored products show a cosmopolitan distribution. Parks and gardens host 52.6% of alien species, where they are frequently introduced with their native hostplant, while 25.8% have colonized agricultural land (Figure 11.5).

11.7 Ecological and economic impact

The impact of most alien Lepidoptera species has not been quantified in detail. However, negative economic impact has been recorded for 16 alien species. The Indian

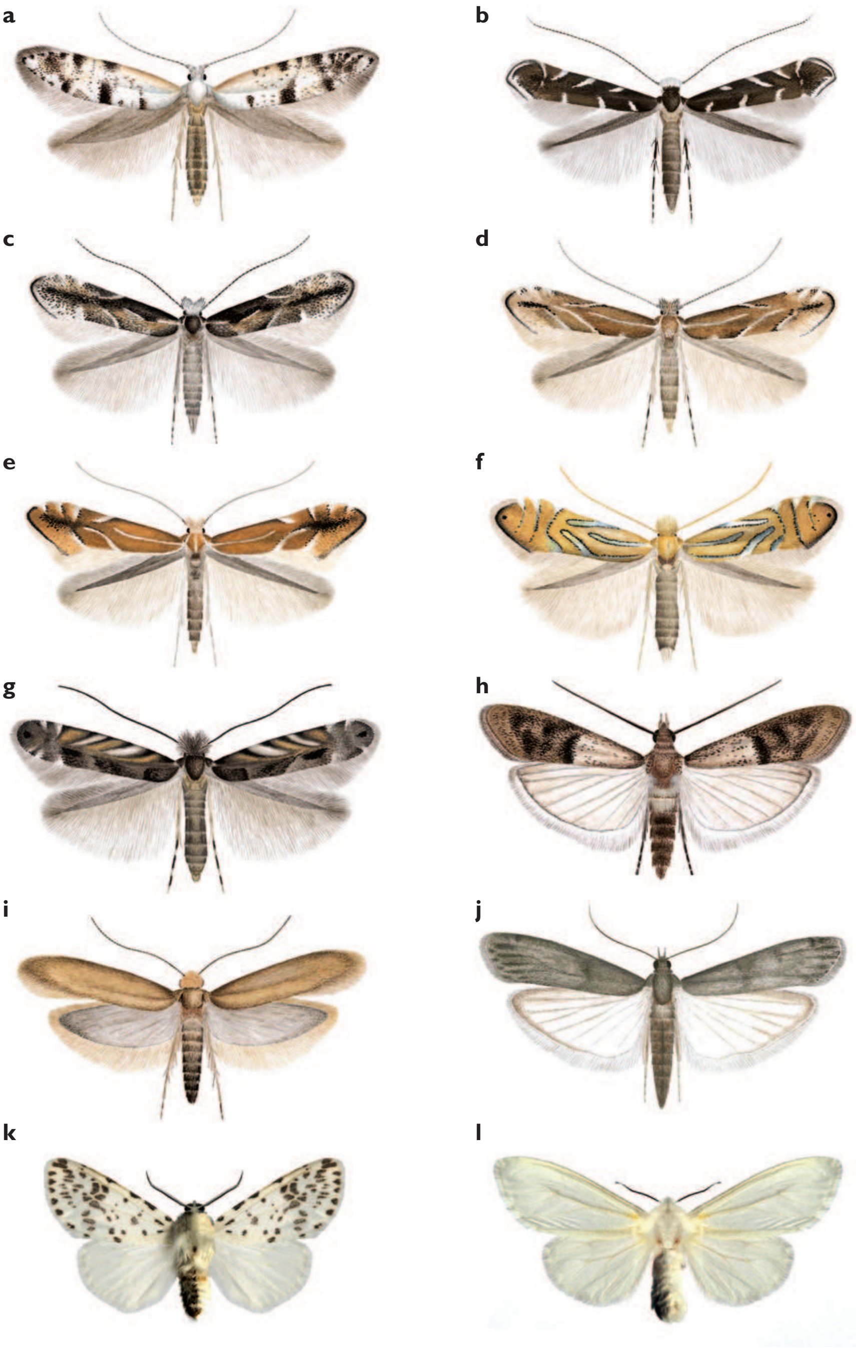

Figure 11.6. Adult habitus of some lepidopteran species alien *to* Europe: **a** *Argyresthia thuiella* **b** *Parectopa robiniella* **c** *Phyllonorycter issikii* winter form **d** *Phyllonorycter issikii* summer form **e** *Phyllonorycter leucographella* **f** *Phyllonorycter platani* **g** *Phyllonorycter robiniella* **h** *Plodia interpunctella* **i** *Tineola bisselliella* **j** *Ephestia kuehniella* **k** *Hyphantria cunea* male **l** *Hyphantria cunea* female (drawings by Aleš Laštůvka).

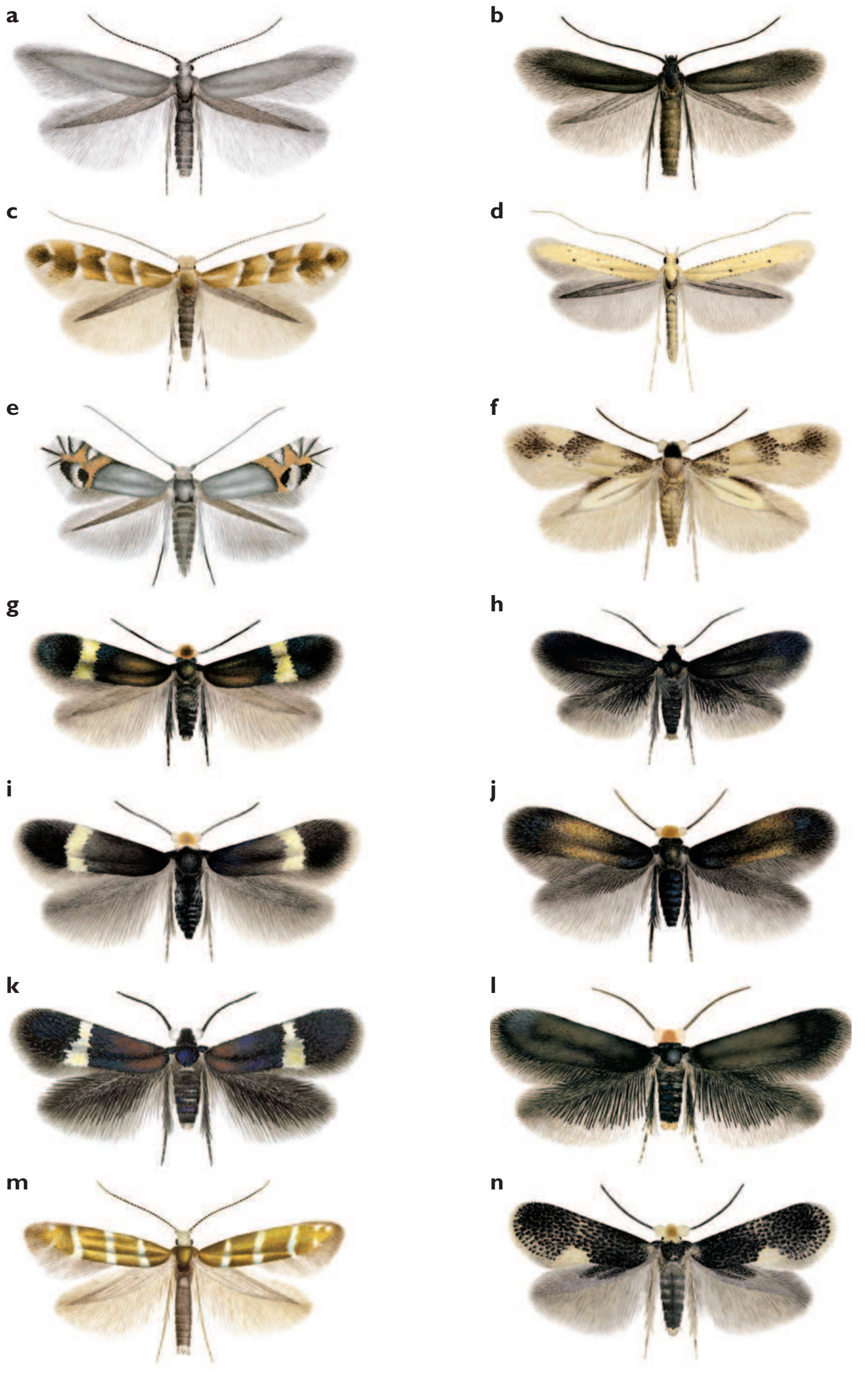

Figure 11.7. Adult habitus of some lepidopteran species alien *in* Europe: **a** *Coleophora laricella* **b** *Coleophora spiraeella* **c** *Cameraria ohridella* **d** *Caloptilia roscipennella* **e** *Leucoptera malifoliella* **f** *Acalyptris platani* **g** *Stigmella aurella* **h** *Stigmella atricapitella* **i** *Stigmella centifoliella* **j** *Stigmella pyri* **k** *Stigmella speciosa* **l** *Stigmella suberivora* **m** *Argyresthia trifasciata;* **n** *Ectoedemia heringella.* (drawings by Aleš Laštůvka).

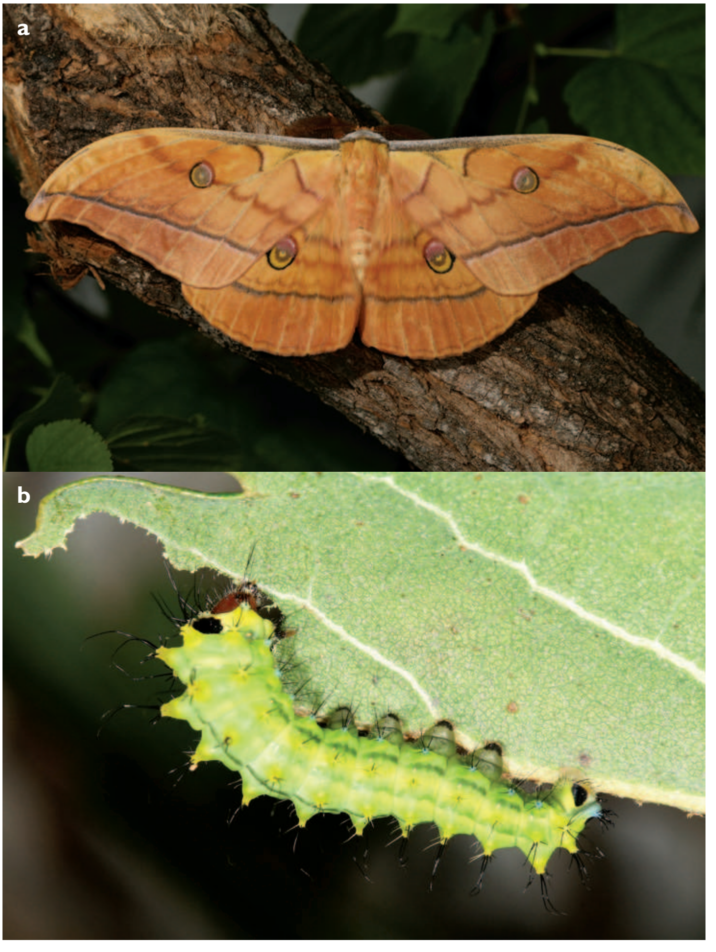

Figure 11.8. Alien saturnid orginating from Asia, *Antherea yamamai* **a** adult **b** 2nd instar larva (credit Zdenek Laštůvka)

Meal Moth *Plodia interpunctella* (Hübner, 1823) may severely affect grain and grain products, dried fruits and seeds in households and warehouses. The Common Clothes Moth *Tineola bisselliella* is another example of a major pest in houses where it feeds on clothes, carpets, rugs, and upholstered furniture. However, along with several other tineids, this species has become rare due to the increase in use of man-made fibres and the dry environment created by central heating (Kimber, 2008). The most serious alien lepidopteran pests in orchards in many parts of Europe include *Grapholita molesta*, *Hyphantria cunea* and *Prays citri*.

Some species can also cause aesthetic impact. Thus, species causing severe infestations can lead to almost complete defoliation of the hostplants. For instance, *C. ohridella* causes premature defoliation of the white-flowered horse-chestnut, *Aesculus hippocastanum*. The trees do not die but the aesthetic impact is so severe that in some countries, heavily infested trees have been felled and removed.

Figure 11.9. Clearwings (Sesiidae) alien *in* Europe. **a** *Pennisetia hylaeiformis* ♂ **b** *Synanthedon andrenaeformis* ♂ **c** *Synynthedon myopaeformis* ♂. (credit Zdenek Laštůvka)

Little is known, however, about the ecological impact of alien Lepidoptera in natural areas of Europe (Kenis et al. 2009). Four alien Lepidoptera species seem to have a potentially important ecological impact: 1) the recently introduced pyralid *Diaphania perspectalis* that could represent a serious threat to topiary Box hedges and plants in nurseries, parks and gardens, and *Buxus* shrubs growing in the wild; 2) *C. ohridella*, that recent studies suggest could have a potential negative impact on native leafminers via apparent competition and could be adapting to *Acer* species in some areas (Péré et al. 2009); 3) the lycaenid *Cacyreus marshalli*, which threatens both native geraniums and *Geranium*-consuming lycaenids (Quacchia et al. 2008); 4) finally, as previously mentioned, *Paysandisia archon* represents a serious threat to the conservation of natural populations of *Chamaerops humilis,* the only native palm in Europe (Montagud Alario 2004, Sarto i Monteys 2002).

Lastly, we recommend that in order to guarantee the well being of natural ecosystems and also to keep track of future additions to the European alien Lepidoptera list, natural areas of special conservation concern like those under the Natura-2000 framework should be monitored more intensively and regularly for the early detection of potential threats, which according to our results are expected to increase.

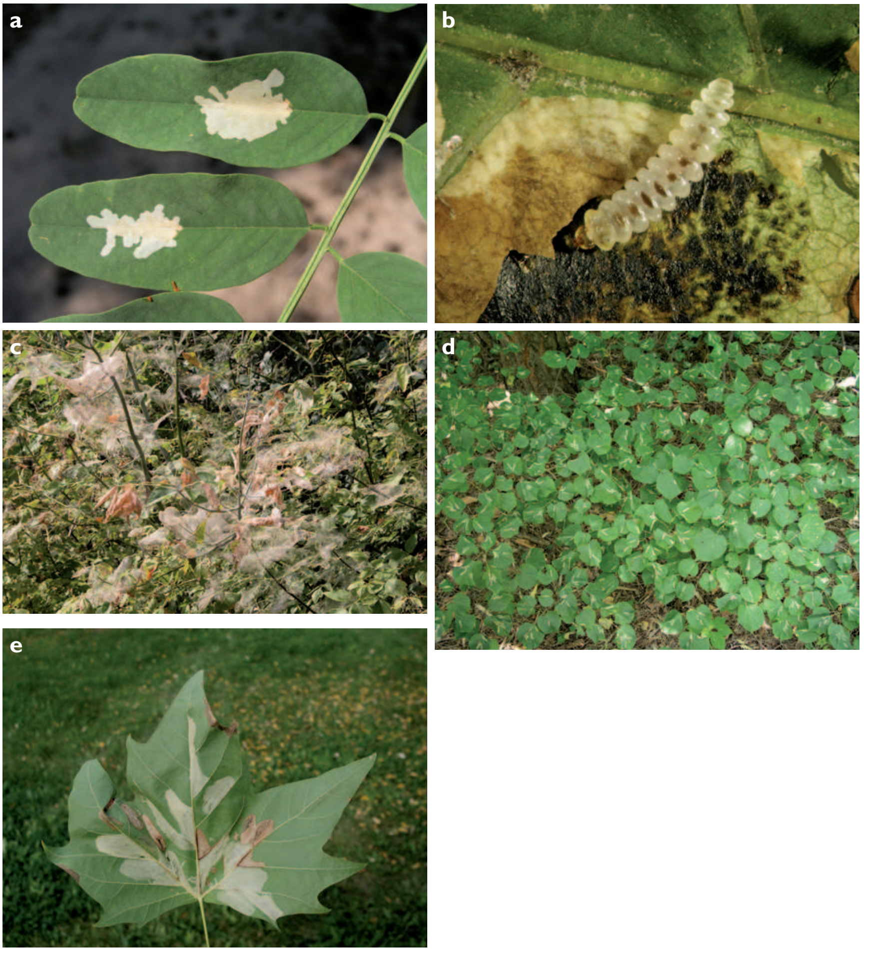

Figure 11.10. Damage by alien lepidopteran larvae. **a** mines of *Parectopa robiniella* on *Robinia* **b** 3rd instar larva of *Cameraria ohridella* extracted from its mine on *Aesculus* **c** damage of *Hyphantria cunea* on *Acer negundo* **d** mines of *Phyllonorycter issikii* on *Tilia* **e** mines of *Phyllonorycter platani* on *Platanus (Credit*: Hana Šefrová).

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References

Aastrup CH (1969) *Phthorimaea operculella* Zell. *Index of Flora and Fauna 1890–1994* 75: 63–64.

Abafi-Aigner L, Pável J, Uhryk F (1896) Ordo Lepidoptera. Budapest: Regia Societas Scientarium Naturalium Hungarica, 82 pp.

Adams RG (1979) *Tinea murariella* Staudinger in Britain (Lepidoptera: Tineidae). *Entomologist's Gazette* 30: 269–270.

Agassiz DJL (1978) *Gelechia sabinella* (Zeller) (Lepidoptera: Gelechiidae), a species new to Britain. *Entomologist's Gazette* 29: 136–137.

Agassiz DJL (1978) Five introduced species, including one new to science, of China Mark moths (Lepidoptera: Pyralidae) new to Britain. *Entomologist's Gazette* 29: 117–127.

Agassiz DJL (1996) Invasions of Lepidoptera into the British Isles. In: Emmet AM (Ed) *The Moths and butterflies of Great Britain and Ireland*. Colchester: Harley Books, 9–36.

Agassiz DJL (1996) *Eccopisa effractella* Zeller (Lepidoptera: Pyralidae) new to the British Isles. *Entomologist's Gazette* 47: 181–183.

Agassiz DJL (1999) The Cypress Tip moth *Argyresthia cupressella* Walsingham, 1890 (Lepidoptera: Yponomeutidae) new to Britain. *Entomologist's Gazette* 50: 11–16.

Agassiz DJL (2007) *Prays peregrina* sp. n. (Yponomeutidae) a presumed adventive species in Greater London. *Nota Lepidopterologica* 30: 407–410.

Aguiar AMF, Karsholt O (2006) Systematic catalogue of the entomofauna of the Madeira archipelago and selvagens islands Lepidoptera vol 1. *Boletim do Museu Municipal do Funchal* (*Historia Natural*), 9: 5–189.

Aguilar L, Miller JY, Sarto i Monteys V (2001) A new lepidopteran family for the European fauna. *SHILAP Revista de Lepidopterologia* 29: 86–87.

Aistleitner U (2003) Erste Nachweise des Geranien-Bläulings *Cacyreus marshalli* Butler, 1898, in der Schweiz (Lepidoptera, Lycaenidae). *Entomologische Berichte Luzern* 49: 151–154.

Amsel HG (1959) Portugiessische Kleinsmetterlinge gesammelt von Teodoro Monteiro, O. S. B. *Anais da Faculdade de Ciencias do Porto* 41: 5–20.

Andres von A (1916) Verzeichnisder während meiner Kriegsgefangenschaft von mir auf Malta gesammelten Lepidoptera. Hemiptera und Coleoptera. *Entomologische Rundschau* 33: 48–49.

Asher JM, Warren R, Fox P, Harding G, Jeffcoate S (2001) The Millennium Atlas of Butterflies in Britain and Ireland. Oxford: Oxford University Press, 433 pp.

Asselbergs JEF (1999) *Arenipses sabella* Hampson, 1901, from South Spain: new to the European fauna; *Thylacoptila paurosema* Meyrick, 1885, new to the fauna of the Canary Islands; *Ancylosis (Ancylosis) albidella* Ragonot, 1888, new to the Spanish fauna (Lepidoptera: Pyralidae, Galleriinae, Phycitinae). *SHILAP Revista de Lepidopterologia* 27: 125–129.

Baeta-Neves CM (1945) Nota sobre a ‚*Lithocolletis platani*' Stgr. (Lepidoptera - Gracillariidae), espécie nova para a Entomofauna de Portugal. *Arquivos do Museu Bocage* 16: 85–88.

Baez M (1998) Mariposas de Canarias. Alcorcón: Rueda, 208 pp.

Baldizzone G (2010) pers. comm. 11/02/10 to DCL

Baraniak E, Walczak U (2000) *Phyllonorycter leucographella* (Zeller, 1850) (Lepidoptera: Gracillariidae) w Polsce. *Wiadomości Entomologiczne* 19: 105–108.

Bathon H (1984) Ein Besuch aus den Tropen: *Callopistria maillardi* in Hessen. (Lepidoptera: Noctuidae). *Mitteilungen Internationaler Entomologischer Verein* 9: 78–80.

Battisti A, Stastny M, Netherer S, Robinet C, Schopf A, Roques, A, Larsson, S (2005) Expansion of geographic range in the Processionary Moth caused by increased winter temperatures. *Ecological Applications* 15: 208423.

Bech K (2009) Fund af storsommerfugle I Danmark 2008. *Lepidoptera Tillæg* 9: 45.

Bednova OV, Belov DA (1999) The Lime Leafminer (Lepidoptera, Gracillariidae) in forest plantations of Moscow and adjacent areas. *Lesnoi Vestnik*, 2: 172–177.

Beirne BP (1940) Note on *Mnesipatris filicivora* Meyr. *Entomologist* 70: 195–196.

Bella S, Ferrauo G (2005) Presence of *Megalorhipida leucodactyla* (Lepidoptera: Pterophoridae) in Sicily: new report for the Italian fauna and notes on the diffusion of its host plant *Boerhavia repens* L. ssp. *viscosa* (Choisy) Maire (Nyctaginaceae). *Biological Invasions* 7: 577–587.

Bella S, Marchese G (2007) First record of *Lantanophaga pusillidactylus* (Walker, 1864) for the Italian fauna. *Bollettino di Zoologia Agraria e di Bachicoltura* 39: 71–74.

Bentinck GA (1963) Bijzondere Lepidoptera voor de Nederlandse fauna. *Entomologische Berichten* 23: 171–172.

Berndt L, Brockerhoff EG, Jactel H, Weis T, Beaton J (2004) Biology and rearing of *Pseudocoremia suavis*, an endemic looper (Lepidoptera: Geometridae) with a history of outbreaks on exotic conifers. *New Zealand Entomologist* 27: 73–82.

Billen W (1999) Ist der Mittelmeernelkenwickler (*Cacoecimorpha pronubana* Hübner) (Lepidoptera: Tortricidae) im Begriff, in Süddeutschland heimisch zu werden? *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 51: 127–128.

Blažič A, Dražumerič M, Hudoklin A (1995) *Machov zbornik. Društvo pedagoških delavcev Dolenjske, Klub za nadarjene učence*. Novo mesto, 85 pp.

Bolchi Serini G, Trematerra P (1989) Comparsa del neartico *Phyllonorycter robiniellus* (Clemens) (Lepidoptera, Gracillariidae) in Italia. *Bollettino di Zoologia Agraria e di Bachicoltura* 21: 193–198.

Bolle G (1921) La Tignola della farina e la sua distruzione. *Allevamenti Palermo* 2: 138–144.

Bond KGM, Nash R, O'Connor JP (2006) An Annotated Checklist of the Irish Butterflies and Moths (Lepidoptera). Dublin: The Irish Biogeographical Society, 177 pp.

Borg J (1899) The Potato Moth - Lita Solanella. Daily Malta Chronicle. 5.

Borg P (1932) The Lepidoptera of the Maltese Islands. Malta: Government Printing Press, 25 pp.

Bradley JD (1959) An illustrated list of the British Tortricidae part II: Olethreutinae. *Entomologist's Gazette* 10: 60–80.

Bradley JD, Tremewan WG, Smith A (1973) *British Tortricoid moths, Cochylidae and Tortricidae: Tortricinae*. London: The Ray Society, 251 pp.

Brua C (2008) La Pyrale du buis *Diaphania perspectalis*. Une nouvelle espèce invasive présente en Alsace. http://sites.estvideo.net/sae/pyrale_du_buis.html.

Budd PA, Goater B (1998) *Eustixia pupula* Hübner, 1823 (Lepidoptera: Pyralidae, Odontiinae), a New World pyralid new to Britain and Europe. *Entomologist's Gazette* 49: 169–170.

Buhl O, Falck P, Karsholt O, Larsen K, Vilhelmsen F Fund af småsommerfugle fra Danmark i 2008 (Lepidoptera). *Entomologiske Meddelelser* 77: In press.

Buhl O, Karsholt O, Larsen K, Nielsen ES, Pallesen G, Palm E, Schnack K (1982) Fund af småsommerfugle i Danmark 1980 (Lepidoptera). *Entomologiske Meddelelser* 49: 49–57.

Buhl O, Andersen EM, Falck P, Jeppesen G, Larsen K (1985) *Callopistria maillardi* (Guenée, 1862) fundet i Danmark (Lepidoptera, Noctuidae). *Lepidoptera* 10: 359–363.

Buhl O, Karsholt O, Larsen K, Palm E, Schnack K (1987) Fund af småsommerfugle fra Danmark i 1984 (Lepidoptera). *Entomologiske Meddelelser* 54: 97–112.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Schnack K (1991) Fund af småsommerfugle fra Danmark i 1989 (Lepidoptera). *Entomologiske Meddelelser* 59: 29–40.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (1994) Fund af småsommerfugle fra Danmark i 1993 (Lepidoptera). *Entomologiske Meddelelser* 62: 105–115.

Buhl O, Falck PJ, Karsholt O, Larsen K, Vilhelmsen F (1997) Fund af småsommerfugle fra Danmark i 1996 (Lepidoptera). *Entomologiske Meddelelser* 65: 149–158.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (1998) Fund af småsommerfugle fra Danmark i 1997 (Lepidoptera). *Entomologiske Meddelelser* 66: 105–115.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (2001) Fund af småsommerfugle fra Danmark i 2000 (Lepidoptera). *Entomologiske Meddelelser* 69: 69–79.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (2003) Fund af småsommerfugle fra Danmark i 2002 (Lepidoptera). *Entomologiske Meddelelser* 71: 65–76.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (2004) Fund af småsommerfugle fra Danmark i 2003 (Lepidoptera). *Entomologiske Meddelelser* 72: 33–46.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (2005) Fund af småsommerfugle fra Danmark i 2004 (Lepidoptera). *Entomologiske Meddelelser* 73: 73–86.

Buhl O, Falck P, Jørgensen B, Karsholt O, Larsen K, Vilhelmsen F (2006) Fund af småsommerfugle fra Danmark i 2005 (Lepidoptera). *Entomologiske Meddelelser* 74: 91–105.

Buhl O, Falck P, Karsholt O, Larsen K, Vilhelmsen F (2007) Fund af småsommerfugle fra Danmark i 2006 (Lepidoptera). *Entomologiske Meddelelser* 75: 89–109.

Buszko J, Vives Moreno A (1992) *Borkhausenia nephrax* Hodges, 1974 (Lepidoptera, Oecophoridae) w Polsce. *Wiadomości Entomologiczne* 11: 101–104.

Buszko J, Nowacki J (2000) The Lepidoptera of Poland. A Distributional checklist. Poznań-Toruń: Scripta Technica, 179 pp.

Butin H, Führer E (1994) Die Kastanien-Miniermotte (*Cameraria ohridella* Deschka & Dimic) ein neuer Schädling an *Aesculus hippocastanum*. *Nachrichtenblatt Der Deutsche Pflanzenschutzdienst* 46: 89–91.

Carnelutti J (1975) Lepidoptera, Mikrolepidoptera. *Porocilo o inventarizaciji favne, vegetacije, skodljivcev in rastlinskih bolezni na obmocju jugoslovansko-avstrijske meje 1974–1975*. Ljubljana: Bioloski institut Jovana Hadzija, 82–156.

Caruana Gatto A (1905) *Seconda Contribuzione alla Fauna Lepidotterologica dell'Isola di Malta – Eteroceri*. Malta: Tipografia del "Malta", 32 pp.

Carvalho de JP (1995) Microlepidoptera of the Madeira and Selvagem Archipelagoes (Insecta Lepidoptera). *Boletim do Museo Municipal do Funchal (Historia Natural)* 4: 559–588.

Carvalho de JP, Aguiar AMF (1997) Pragas dos citrinos na Ilha da Madeira. Funchal: RAM/SRAFP,INIA/EAN, 411 pp.

Casale A (1973) Popolazione di *Antheraea yamamai* (Guér.Mén.) spontaneamente ambientata in peculiare autonomo biotopo italiano (Lep. Saturniidae). *Annali della facoltà di Scienze agrarie dell'Università di Torino* 8: 309–324.

Chalmers-Hunt JM (1985) *Monochroa niphognatha* Gozmány, 1953 and *Athrips rancidella* Herrich-Schaffer, 1854 (Lepidoptera: Gelechiidae), new to the British fauna. *Entomologist's Record and Journal of Variation* 97: 20–24.

Chambon J-P, Fabre J-P, Khemeci M (1990) Trois nouvelles Tordeuses d'Algérie nuisibles aux Conifères: *Epinotia algeriensis* n. sp. (Olethreutinae, Eucosmini), *Lozotaenia cedrivora* n. sp. et *Dichelia numidicola* n. sp. (Tortricinae, Archipini) [Lep. Tortricidae]. *Bulletin de la Société entomologique de France* 95: 131–138.

Ciampolini M (1973) *Opogona sacchari* Bojer dannosa a piante ornamentali. *Notiziario sulle malattie della piante* 88: 88–89.

Cocquempot C, Nel J (2009) *Bucculatrix chrysanthemella* (Rebel, 1896) introduit en France (Lepidoptera, Bucculatricidae). *L'Entomologiste* 65: 71–73.

Colazza S, Privitera S, Campo G, Peri E, Riolo P (2005) *Paysandisia archon* (Lepidoptera: Castniidae) a new record for Sicily. *L'Informatore Fitopatologico* 5: 56–57.

Coldewey H, Vári L (1947) Lijst van op Schovenhorst aangetroffen vlinders. In: Oudemans TC (ed) *Gedenkboek ter gelegenheid van het 100-jarig bestaan van Schovenhorst - 1948*. Netherlands: Putten, 283–299.

Constanzi M, Cocquempot C, Nel J, Belgiovine M (2008) Un nuovo minatore fogliare su margherita da vaso in Liguria. *Colture Protette* 37: 74–78.

Corley MFV, Gardiner AJ, Cleere N, Wallis PD (2000) Further additions to the Lepidoptera of Algarve, Portugal (Insecta: Lepidoptera). *SHILAP Revista de Lepidopterologia* 28: 245–319.

Corley MFV (2005) Further additions to the Lepidoptera of Algarve, Portugal. II (Insecta: Lepidoptera). *SHILAP Revista de Lepidopterologia* 33: 347–364.

Corley MFV, Maravalhas E, Passos de Carvalho J (2006) Miscellaneous additions to the Lepidoptera of Portugal (Insecta: Lepidoptera). *SHILAP Revista de Lepidopterologia* 34: 407–427.

Costa Seglar M, Vives Quadras JM (1976) *Epichoristodes acerbella* Walk, nuevo tortrícido, plaga de los claveles, en la Península Ibérica. *SHILAP Revista de Lepidopterologia* 4: 233–234.

Csoka G (2001) Recent invasions of five species of leafmining Lepidoptera in Hungary. In: Liebhold AM, McManus ML, Otvos IS and Fosbroke SLC (eds) *Integrated management and dynamics of forest defoliating insects*: U.S. Department of Agriculture, Forest Service, Northeastern Research Station., pp. 31–36.

DAISIE (2008) List of species alien in Europe and to Europe. In: Drake JA (ed) Invading Nature: Springer Series in Invasion Ecology. Dordrecht: Springer, pp. 133–263

De Crombrugghe E (1906) Catalogue raisonné des Microlépidoptères de Belgique. *Mémoires de la Société entomologique de Belgique* 13: 1–172.

De Crombrugghe E (1909) Observations microlépidoptérologiques faites en 1908. *Annales de la Société Entomologique de Belgique* 53: 44–47.

De Fré C (1858) Catalogue des Microlépidoptères de la Belgique. *Annales de la Société Entomologique de Belgique* 2: 45–162.

De Graaf HW (1851) Nederlandsche schubvleugelige insekten (Lepidoptera). *Bouwstoffen voor eene Fauna van Nederland* 1: 1–55.

De Prins W (1983) Systematische Naamlijst van de Belgische Lepidoptera. *Entomobrochure* 4: 1–57.

De Prins W (1989) Enkele soorten Microlepidoptera nieuw voor de Belgische fauna (Lepidoptera: Opostegidae, Ochsenheimeriidae, Coleophoridae, Gelechiidae, Cochylidae, Pterophoridae). *Phegea* 17: 49–52.

De Prins W (1994) *Phyllonorycter leucographella* (Zeller, 1850), een nieuwe soort voor de Belgische fauna (Lepidoptera: Gracillariidae). *Phegea* 22: 125–128.

De Prins W (1996) Enkele nieuwe en interessante soorten Microlepidoptera voor de Belgische fauna (Lepidoptera: Nepticulidae, Yponomeutidae, Coleophoridae, Gelechiidae). *Phegea* 24: 137–140.

De Prins W, Puplesiene J (2000) *Cameraria ohridella*, een nieuwe soort voor de Belgische fauna (Lepidoptera: Gracillariidae). *Phegea* 28: 1–6.

De Prins W, Groenen F (2001) *Phyllonorycter robiniella*, een nieuwe soort voor de Belgische fauna (Lepidoptera: Gracillariidae). *Phegea* 29: 159–160.

De Prins W (2005) Interessante waarnemingen van Lepidoptera in België in 2004 (Lepidoptera). *Phegea* 33: 1–8.

De Prins W (2007) Interessante waarnemingen van Lepidoptera in België in 2006 (Lepidoptera). *Phegea* 35: 1–20.

De Sélys-Longchamps E (1844) Enumération des insectes Lépidoptères de la Belgique. *Mémoires de la Société royale des Sciences de Liége* 2: 1–35.

Dei A (1871) Sui danni degli insetti nelle campagna senesi durante l'anno 1871. *Bullettino della Società Entomologica Italiana, Firenze* 3: 360–365.

Della Beffa G (1931) Notizie su alcuni Microlepidotteri nocivi o poco noti pel Piemonte. *Bollettino Laboratorio Sperimentale e Osservatorio Fitopatologia* 6: 1–7.

Demokidov KE (1916) On the life history of the tea moth, *Parametriotes theae* Kusn. (Lepidoptera, Tineidae). *Revue Russe d'Entomologie* 15: 618–626.

Deurs W (1958) Nye og sjældne sommerfugle 1956. *Entomologiske Meddelelser* 28: 169–171.

Domínguez García-Tejero F (1943) Las plagas de los frutales en España y su distribución geográfica. *Boletín de Patología Vegetal y entomología Agrícola* 12: 329–352.

Drenowsky A (1909) Izsledvaniya vurhu peperudnata fauna na Rila planina. *Sbornik narodni umotvoreniya nauka I knizhnina* 25: 1–23.

Drensky P (1930) Bolesti I nepriyateli po zhitnite rasteniya v Bulgaria. *Svedeniya po zemedelieto* 11: 3–54.

Du Merle P (1988) Les Recherches sur les insectes nuisibles aux forêts dans le Sud-Est de la France. *Revue forestière française* 40: 297–301.

Dufrane A (1960) Microlépidoptères de la faune belge (neuvième note). *Bulletin du Musée royal d'Histoire naturelle de Belgique* 36: 1–16.

Emmet AM, Watkinson IA, Wilson MR (1985) Gracillariidae. In: Heath J and Emmet AM (Eds) *The Moths and Butterflies of Great Britain and Ireland. Volume 2 Cossidae –Heliodinidae*. Great Horkesley: Harley Books, 460

Emmet AM (1988) *A Field Guide to the Smaller British Lepidoptera*. London: British Entomological and Natural History Society, 288 pp.

Espinosa B, Di Muccio P, Russo G (2003) *Paysandisia archon*, una minaccia per le nostre palme. *L'Informatore Agrario* 59: 61.

Ermolaev IV, Motoshkova NV (2008) Biological invasion of the Lime Leafminer Lithocolletis issikii Kumata (Lepidoptera, Gracillariidae): interaction if the moth with the host plant. *Entomological Review*, 88: 1–9.

Essl F, Rabitsch W (2002) Neobiota in Osterreich. Wien: Umweltbundesamt, 432 pp.

Fabre J-P (1997) Geographical distribution of the tortricid moth *Epinotia cedriceda* (Lepidoptera: Tortricidae) within the natural and artificial ranges of the cedar trees *Cedrus atlantica* and *C. libani*. *European Journal of Entomology* 94: 485–494.

Fabre J-P, Avci M, Chalon A (2001) La tordeuse *Dichelia cedricola* Diakonoff, un ravageur d'Asie Mineure potentiellement important pour la France. *Revue forestière française* 2: 131–138.

Falck P, Karsholt O (1993) *Cydia grunertiana* (Ratzeburg, 1868), stat. rev. - an ignored species of Tortricidae. *Nota Lepidopterologica* 16: 79–90.

Feron M (1973) Apparition de la pyrale du riz (*Chilo suppressalis*) en Camargue. *Bulletin d'information des riziculteurs de France* 145: 13–15.

Filipjev NN (1932) Verzeichnis der schädlichen Insekten der paläarktischen Region. Leningrad: Vses. akad. s.-ch. nauk im. V. I. Lenina, Inst. zaščity rastenij, 430 pp.

Fjelddalen J (1965) Angrep av sydafrikansk nellikvikler i Norge. *Gartneryrket* 55: 340–342.

Fologne E (1859) Supplément au catalogue des lépidoptères de Belgique. *Annales de a Société Entomologique de Belgique* 3: 107–132.

Ford EB (1945) *Butterflies*. London: Collins, 368 pp.

Franco JC, Ramos AP, Moreira I (2006) *Infra-estruturas ecológicas e protecção biológica: caso dos citrinos*. Lisboa: ISA Press, 106 pp.

Frankenhuyzen Av (1974) *Argyresthia thuiella* (Pack.) (Lep., Argyresthiidae). *Entomologische Berichten* 34: 106–111.

Frankenhuyzen Av (1983) *Phyllonorycter platani* (Staudinger, 1870) (Lep.: Gracillariidae), een bladmineerder op plataan in Nederland. *Entomologische Berichten* 43: 19–25.

Fric Z (2005) *Colotis evagore* (Klug, 1829) advancing northwards in Spain (Lpidoptera: Pieridae). *SHILAP Revista de Lepidopterologia* 33: 169–171.

Frohawk FW (1940) Liberated butterflies. *Entomologist* 73: 214.

Fuentes Garcia FJ (1997) *Cacyreus marshalli* Butler, 1898 llega a Portugal. *SHILAP Revista de Lepidopterologia* 25: 208.

Gaedike R, Heinicke W (1999) Verzeichnis der Schmetterlinge Deutschlands (Entomofauna Germanica 3). Dresden: Entomologische Nachrichten und Berichte. 216 pp.

Gaedike R, Karsholt O (2001) Contribution to the Lepidoptera fauna of the Madeira Islands. Part 2. Tineidae, Acrolepiidae, Epermeniidae. *Beiträge zur Entomologie* 51: 161–213.

García Mercet R (1926) *Asociación Española para el Progreso de las Ciencias, Congreso de Coimbra* 6: 177–184.

Garijo C, Garcia E (1994) *Phyllocnistis citrella* (Stainton, 1856) (Insecta: Lepidoptera: Gracillariidae: Phyllocnistinae) en los cultivos de cítricos en Andalucía (Sur España): Biología, ecología y control de la plaga. *Boletín de Sanidad Vegetal, Plagas* 20: 815–881.

Geiter O, Homma S, Kinzelbach R (2001) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltforschungsplan des Bundesministeriums fur Umwelt, Naturschutz und Reaktorsicherheit. 174 +36 +31 +52 pp.

Gerasimov AM (1949) Opisanie ognevki *Chilo tadzhikiellus* Gerasimov i sovki Sesamia cretica striata Stgr., vredyashchikh sakharnomu trostniku v Tadzhikistane. *Trudy Zoologicheskogo Instituta AN SSSR* 8: 703.

Gielis C (1996) Microlepidoptera of Europe, Volume 1: Pterophoridae. Stenstrup: Apollo Books, 222 pp.

Gilbert M, Grégoire J-C, Freise JF, Heitland W (2004) Long-distance dispersal and human population density allow the prediction of invasive patterns in the horse chestnut leafminer *Cameraria ohridella*. *Journal of Animal Ecology* 73: 459–468.

Giunchi P (1957) La *Paralipsa gularis* Zell. nell'Emilia (Lepidoptera Galleriidae). *Bollettino della Società entomologica Italiana* 87: 21–22.

Glavendekić M, Mihajlović L, Petanović R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro. In: Alford DV and Backhouse GF (Eds) *Plant Protection and Plant Health in Europe. Introduction and Spread of Invasive Species. Symposium Proceedings No. 81*. Alton: British Crop Protection Council, 229–230.

Goater B (1986) *British Pyralid Moths: A Guide to Their Identification*. Colchester: Harley Books, 176 pp.

Goater B, Nuss M, Speidel W (2005) Pyraloidea I: Acentropinae, Evergestinae, Heliothelinae, Schoenobiinae, Scopariinae. In: Huemer P, Karsholt O and Lyneborg L (Eds) *Microlepidoptera of Europe*. Stenstrup: Apollo Books, 304.

Gomboc S (2003) Novi vrsti listnih zavrtačev v Sloveniji. [New species of leaf miner in Slovenia]. *Zbornik predavanj in referatov 6. slovenskega posvetovanja o varstvu rastlin, 4–6 marec 2003. [Slovenian Conference on Plant Protection, Zreče, 4.6. March 2003], Zreče*, p. 423–429.

Gomboc S, Lasan M, Deutsch H New and interesting records of Lepidoptera in Slovenia – I. *Acta entomologica Slovenica*. Volume: 18: In press.

Gómez de Aizpúrua C (2004) *Orugas y mariposas de Europa, II. Rhopalocera*: Organismo Autónomo de Parques Nacionales. Ministerio de Medio Ambiente, 219 pp.

Good I (1995) On the question of silk in pre-Han Eurasia. *Antiquity* 69: 959–968.

Gozmány LA (2008) *Symmocidae*. Keltern: Goecke and Evers, 558 pp.

Groenen F, De Prins W (2004) *Cydia grunertiana*, nieuw voor de Belgische fauna (Lepidoptera: Tortricidae). *Phegea* 32: 113–115.

Gustaffson B (2010) Svenska Fjarilar: Welcome page of the World Plutellidae. http://www2.nrm.se/en/svenska_fjarilar/p/plutella_porrectella.html.

Hacker HH, Legrain A, Fibiger M (2008) Revision of the genus *Acontia* Ochsenheimer, 1816 and the tribus Acontiini Guenée, 1841 (Old World) (Lepidoptera: Noctuidae: Acontiinae). *Esperiana Buchreihe zur Entomologie* 14: 1–686.

Hamburger M, Zarabi L, Weiss M, Argaman Q, Kuslitzky W, Kein, Z (2000) False codling moth (*Cryptophlebia leucotreta*) in Israel. *Phytoparasitica* 29: 84.

Hance T (1991) Infestation de pâtes de fruits alimentaires par *Ephestia calidella* Guénée (Lepidoptera: Pyralidae). *Bulletin et Annales de la Société royale belge d'Entomologie* 127: 338–340.

Hancock EG (1984) *Oligostigma bilinealis* Snellen (Lepidoptera: Pyralidae), a second British record. *Entomologist' s Gazette* 35: 18.

Harizanova V, Stoeva A, Mohamedova M (2009) Tomato Leaf Miner, *Tuta absoluta* (Povolny) (Lepidoptera: Gelechiidae) – First Record In Bulgaria. *Agricultural Science and Technologies* 3: 95–98.

Heath J, Emmet AM (1983) The Moths and Butterflies of Great Britain and Ireland: Vol. 10, Noctuidae (Part 2) and Agaristidae. London and Colchester: Harley Books, 459 pp.

Heath J, Emmet AM (1985) The Moths and Butterflies of Great Britain and Ireland Volume 2: Cossidae to Heliodinidae. London and Colchester: Harley Books, 460 pp.

Heath J, Emmet AM (1996) The Moths and butterflies of Great Britain and Ireland, Yponomeutidae to Elachistidae. London and Colchester: Harley Books, 454 pp.

Heckford RJ (2004) *Anatrachyntis simplex* (Walsingham, 1891) (Lepidoptera: Cosmoptereigidae), an adventive species new to the British Isles and a larval description. *Entomologist's Gazette* 55: 95–101.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw M, Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) Audit of non-native species in England. English Nature Research Reports N° 662: Peterborough: English Nature, 81 pp.

Hind SH (2000) *Tachystola acroxantha* (Meyrick) (Lep:Oecophoridae) around Manchester: history and current status. *Entomologist's Record and Journal of Variation* 112: 127–128.

Hoffmeyer S (1962) De danske Ugler 2. Århus: Universitetsforlaget i Aarhus, 387 pp.

Hollingsworth T (2004) Status of *Paysandisia archon* (Burmeister) (Lepidoptera: Castniidae) in southern Europe. *British Journal of Entomology and Natural History* 17: 33–34.

Holloway J (1998) Geranium bronze *Cacyreus marshalli Atropos* 4: 3–6.

Honey MR (1994) *Pardasena virgulana* (Mabille) (Lepidoptera: Noctuidae), a species not previously found in the wild in Britain. *British Journal of Entomology and Natural History* 7: 33–34.

Hrdý I, Krampl F (1977) Faunistic records from Czechoslovakia. *Acta Entomologica Bohemoslovaca* 74: 286.

Hrubý K (1964) *Prodromus Lepidopter Slovenska*. Bratislava: Slovenskej Akademie Vied, Bratislava, 962 pp.

Huemer P, Rabitsch W (2002) Schmetterlinge (Lepidoptera) [Section 6.3.1] In: Essl F and Rabitsch W (Eds) *Neobiota in Österreich*. Wien: Umweltbundesamt, 354–362.

Huisman KJ, Koster JC (1995) Interessante Microlepidoptera uit Nederland in het jaar 1992 (Lepidoptera). *Entomologische Berichten* 55: 53–67.

Huisman KJ, Koster JC, Nieukerken van EJ, Ulenberg SA (2003) Microlepidoptera in Nederland in 2000. *Entomologische Berichten* 63: 88–102.

Hyden N, Jilg K, Östman T (2006) Fjärilar: Ädelspinnare-tofsspinnare.Lepidoptera: Lasiocampidae-Lymantriidae. Uppsala: *Nationalnyckeln* 480 pp.

Ippolito R, Parenzan P (1981) Osservazioni su catture di Lepidotteri in agro di Polignano (Bari). *Entomologica* 16: 143–182.

Ivinskis P (1976) Микрочешуекрылые Литовской ССР (3. Огневки (Lepidoptera, Pyraloidea)). Lietuvos TSR MA darbai. [Microlepidoptera of the Lithuanian SSR. 3. Pyralid moths (Lepidoptera, Pyraloidea)]. *Lietuvos TSR Moksku Akademijos darbai, C Serija Biologijos. Mokslai* 3: 73–82.

Ivinskis P (1988) Новые и редкие для Литовской ССР виды насекомых. Сообщения и описания 1987 года. [73 species of Lepidoptera, new to the Lithuanian SSR, found in 1968–1987. In: Jonaitis V (Ed), [New and rare insect species for Lithuania. Records and descriptions].Vilnius: Institute of Zoology and Parasitology, 47–60

Ivinskis (1993) Checklist of the Lithuanian Lepidoptera. Vilnius: Institute of Ecology, 220 pp.

Ivinskis P, Mozūraitis R (1995) 13 new and 48 rare for the Lithuanian fauna Lepidoptera species. In: Jonaitis V (Ed) New and rare for Lithuania insect species. Records and descriptions of 1994–1995. Vilnius: Institute of Ecology, 153–160.

Ivinskis P (2004) Lepidoptera of Lithuania. Vilnius: Institute of Ecology, 380 pp.

Ivinskis P, Rimsaite J (2008) Records of *Phyllonorycter robiniella* (Clemens, 1859) and *Parectopa robiniella* Clemens, 1863 (Lepidoptera, Gracillariidae) in Lithuania. *Acta Zoologica Lituanica* 18: 130–133.

James T (2008) Common Forest Looper *Pseudocoremia suavis* (Butler): a new species to Britain. *Atropos* 33: 13–16.

Janežič F (1951) *Plant protection against pests and diseases*. Ljubljana: DZS, 567 pp.

Janežič F (1968) *Kako varujemo rastlinam zdravje?* Ljubljana: DZS, 232 pp.

Janmoulle E (1938) Assemblée mensuelle du 4 juin 1938. *Annales de la Société Entomologique de Belgique* 78: 250–253.

Janmoulle E (1954) *Lithocolletis platani* Stgr. en Belgique. *Lambillionea* 54: 34.

Janmoulle E (1965) Remarques sur la faune belge (suite). *Lambillionea* 64: 12–13.

Janmoulle E (1974) Espèces nouvelles pour la faune belge (suite). *Lambillionea* 74: 16.

Jannone G (1966) Risultati di alcuni controlli fitosanitari su vegetali e prodotti vegetali esteri nel porto di Genova. *Rivista di Agricoltura Subtropicale e Tropicale* 60: 5–34.

Johansson R, Nielsen ES, Nieukerken van EJ, Gustafsson B (1990) *The Nepticulidae and Opostegidae (Lepidoptera) of North West Europe*, 730 pp.

Jones MJ, Lace LA (1992) The speckled wood butterflies *Pararge xiphia* and *P. aegeria* (Satyridae) on Madeira: distribution, territorial behaviour and possible competition. *Biological Journal of the Linnean Society* 46: 77–89.

Jørgensen J (1982) Havebrugszoologi for have og landskab. Copenhagen: DSR forlag, 300 pp.

Jürivete U, Kaitila J, Kesküla T, Nupponen K, Viidlepp J, Õunap, E (2000) *Eesti liblikad. Kataloog. Estonian Lepidoptera. Catalogue*. Talinn: Eesti Lepidopteroogide Selts, 151 pp.

Karsholt O, Nielsen ES (1976) Systematisk fortegnelse over Danmarks sommerfugle. Klampenborg: Scandinavian Science Press, 128 pp.

Karsholt O (1994) Nogle indslæbte sommerfugle i Danmark, samt bemærkninger om dette emne (Lepidoptera). *Entomologiske Meddelelser* 62: 1–5.

Karsholt O, Nielsen ES (1986) The Lepidoptera described by C. P. Thunberg. *Entomologica scandinavica*, 16: 433–463.

Karsholt O, Nielsen PS (1998) Revideret katalog over de danske Sommerfugle. Copenhagen: Entomologisk Forening, 144 pp.

Karsholt O, Kristensen NP (2003) Kastaniemøllet: et kønt nyt skadedyr i Danmark. *Dyr i natur og museum* 1: 9–11.

Karsholt O, Nieukerken van EJ (2004) Lepidoptera, Moths. Fauna Europaea version 1.3. http://www.faunaeur.org.

Karsholt O, Sinev SY (2004) Contribution to the Lepidoptera fauna of the Madeira Islands. Part 4. Blastobasidae. *Beiträge zur Entomologie* 54: 387–463.

Karsholt O, Vieira V (2005) Lepidoptera. In: Borges PAV, Cunha R, Gabriel R, Frias Martins A, Silva L and Vieira V (Eds) *A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Direccao Regional do Ambiente and Universidade das Açores, 317.

Karvonen J (1983) *Cryptophlebia leucotreta* imported into Finland (Lepidoptera, Tortricidae). *Notulae Entomologicae* 63: 94.

Katsogiannos P, Koveos DS (2001) Integrated *Prunus* pest control in an integrated crop management. *III Panellenic Meeting of Plant Protection*, *Larissa-Greece*, p. 165–178.

Kenis M (2005) Insects. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. CABI Bioscience Switzerland centre, 131–212.

Kenis M, Auger-Rozenberg M-A, Roques A, Timms L, Péré C, Cock MJW, Settele J, Augustin S, Lopez-Vaamonde C (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Kimber I (2008) UK Moths. Your Guide to the Moths of Great Britain and Ireland. http://www.ukmoths.org.uk/index.php.

King GE (2000) Aportación al conocimiento de los Pterophoridae en España: *Lantanophaga pusillidactyla* (Walker, 1864), especie nueva para España y para Europa. *SHILAP Revista de Lepidopterologia* 28: 341–343.

Klimesch J (1979) Beiträge zur Kenntnis der Microlepidopteren-Fauna des Kanarischen Archipels. 2. Beitrag. Bucculatricidae, Gracillariidae, Phyllocnistidae, Lyonetiidae. *Vieraea* 8: 147–186.

Kollar (1854) *Bombyx Cynthia. Verhandlungen des zoologisch-botanischen Vereins in Wien* 4: 114.

Koster JC, Sinev SY (2003) Momphidae, Batrachedridae, Stathmopodidae, Agonoxenidae, Cosmopterigidae, Chrysopeleiidae. Vol 5 In: P. Huemer, Karsholt O and Lyneborg L (Eds) *Microlepidoptera of Europe*, pp. 1–387.

Koster JC, Sammut P (2006) Faunistic notes on Momphidae, Batrachedridae, Statmopodidae and Cosmopterigidae from the Maltese Islands. *Nota Lepidopterologica* 29: 49–63.

Kristensen NP, Skalski AW (1999) Phylogeny and paleontology. In: Kristensen NP (Ed) *Lepidoptera: Moths and Butterflies. 1. Evolution, Systematics, and Biogeography*. Berlin and New York: De Gruyter, 7–25.

Kuchlein JH, van Lettow C (1999) The Dutch species of *Borkhausenia*, with *B. nefrax* as an addition to the Dutch list (Lepidoptera: Oecophoridae). *Entomologische Berichten* 59: 23–29.

Kullberg J, Mikkola K (2001) Amerikasta kotoisin oleva koisalaji *Vitula edmandsii* (Packard, 1865) (Pyralidae) leviämässä Suomeen [*Vitula edmandsii* (Packard, 1865) (Pyralidae) new to Finland]. *Baptria* 26: 6–7.

Kyparissoudas DS (1989) Control of *Cydia molesta* (Busck) by mating disruption using Isomate-M pheromone dispensers in northern Greece. *Entomologia Hellenica* 7: 3–6.

Łabanowski G, Soika G (1998) Szrotówek kasztanowcowiaczek zagraża kasztanowcom w Polsce. *Ochrona Roślin* 12: 12.

Langmaid J, Porter J, Collins GA (2007) *Bucculatrix ulmifoliae* M. Hering, 1931 (Lep.: Bucculatricidae) resident in England. *Entomologist's Record and Journal of Variation* 119: 195–201.

Laštůvka Z, Liška J, Vávra J, Elsner V, Laštůvka A, Marek J, Dufek T, Dvořák M, Kopeček F, Petrů M, Skyva J, Vítek, P (1994) Faunistic records from the Czech Republic - 18. *Klapalekiana* 30: 197–206.

Leclant F (1969) Sur la Biologie d'*Epinotia (Evetria) cedricida* Diakonoff. Grave ravageur du Cèdre en France. (Lep. Tortricidae). *Annales de la Société Entomologique de France* 5: 397–405.

Lederer J (1863) Verzeichnis der von Herrn Johann und Frau Ludmilla Haberhauer 1861 und 1862 bei Warna in Bulgarien und Slivno in Rumelien gesammelten Lepidopteren. *Wiener Entomologische Monatschrift* 7: 17–47.

Lepidopterologen Arbeitsgruppe (2000) *Schmetterlinge und ihre Lebensräume: Arten - Gefährdung - Schutz. Tagfalter und ihre Lebensräume, Arten*. Verlag: Pro Natura, 914 pp.

Letellier M (2004) Une noctuelle exotique, *Acontia crocata* (Guenée, 1852), capturée dans les Deux-Sèvres (Lepidoptera, Noctuidae, Acontiinae). *Alexanor* 23: 45–47.

Lhomme L (1946–1963) Microlépidoptères, Deuxième partie (fasc. 4–7 Tineina). *Catalogue des Lépidoptères de France et de Belgique. Volume II*. Paris: L. Lhomme, 489–1253.

Lindeman KE (1880) O povrezhdenii zeren khlebnykh zlakov v Kubanskoi oblasti mol'yu *Gelechia cerealella*. *Zemledel'cheskaya gazeta* 37–38: 611–613.

Linnaeus C (1758) *Systema naturæ per regna tria naturæ, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. Holmiae: Laurentii Salvii, 824 pp.

Liotta G, Mineo G (1963) Osservazioni sulla biologia del *Prays citri* Mill. in Sicilia (Tignola degli agrumi o verme della zagara), Lep. Yponomeutidae (II nota). *Bollettino dell'Istituto di Entomologia Agraria e dell'Osservatorio di Fitopatologia di Palermo* 5: 75–104.

Luciano P, Lentini A, Battisti A (2007) Prima segnalazione di *Traumatocampa pityocampa* per La Sardegna. [First record of *Traumatocampa pityocampa* in Sardinia]. *Proceedings XXXI Congresso Nazionale Italiano di Entomologia*, *Campobasso*, p. 273.

Luig J, Kesküla T (1995) Catalogus lepidopterorum Estoniae. Tartu Eesti liblikaliste nimestik, 130 pp.

Maček J (1968) Listni zavrtači Slovenije. II (The leaf miners of Slovenia II). *Zbornik Biotehničke fakultete, Kmetijstvo* 15 A: 55–59.

Maček J (1976) Untersuchungen zur hyponomologischen Fauna Sloweniens. II. *Acta Entomologica Jugoslavica* 12: 59–65.

Maček J (1982) Listni zavrtači Slovenije. XII. *Zbornik Biotehničke fakultete, Kmetijstvo* 39: 173–180.

Mallet J (2007) The Lepidoptera Taxome Project Draft Proposals and Information. http://www.ucl.ac.uk/taxome/lepnos.html.

Marabuto E (2006) The occurrence of a neotropical hawkmoth in Portugal: *Agrius cingulatus* (Fabricius, 1775) (Lep.: Sphingidae). *Boletín Sociedad Entomológica Aragonesa* 38: 163–166.

Marek J, Laštůvka A, Vávra J (1991) Faunistic records from Czechoslovakia. *Acta Entomologica Bohemoslovaca* 88: 217–222.

Marek J, Bártová E (1998) *Duponchelia fovealis* Zeller, 1847, nový škůdce skleníkových rostlin v České republice [*Duponchelia fovealis* Zeller, 1847, a new pest of glasshouse plants in the Czech Republic] (Lepidoptera, Pyralidae, Pyraustinae). *Plant Protection Science* 34: 151–152.

Mariani M (1941–43) Fauna Lepidopterorum Italiae. Parte I. Catalogo ragionato dei Lepidotteri d' Italia. *Giornale di Scienze naturali ed economiche, Palermo* 42 (1940–41) (Mem. 3): 1–237.

Martin M (1991) Catalogus Microlepidopterorum Estoniae. Tartu: Eesti liblikaliste nimestik, 56 pp.

Martinez M, Coutin R (1985) Un nouveau ravageur occasionnel: la phalène americaine des plantes seches. *Phytoma. La Défense des Végétaux* 368: 40–41.

Mehl R (1977) Sommerfugler som forekommer i hus og lagrede varer i Norge. *Atalanta norvegica* 3: 41–48.

Mehl R (1979) Fikenmøll, *Ephestia figuliella*, *Ephestia calidella* og johannesbrødmøll, *Ectomyelois ceratoniae*, (Lepidoptera: Phycitidae) i importerte matvarer i Norge. *Atalanta norvegica* 3: 107–110.

Mendes C (1904) Lepidoptera do Portugal. II. Lepidopteros da região de S. Fiel (Beira Baixa). *Brotéria, Série Zoológica* 3: 223–254.

Mendes C (1905) Lepidoptera do Portugal. II. Lepidopteros da região de S. Fiel (Beira Baixa). *Brotéria, Série Zoológica* 4: 166–177.

Mendes C (1910) Lepidopteros de Portugal. I. Lepidópteros dos Arredores de Torres Vedras. *Brotéria, Série Zoológica* 9: 110–129.

Mihelakis SE (1997) *Phyllocnistis citrella* Stainton, Gracillariidae, the new insect pest in our citrus groves. *VI National Entomological Congress in Greece*

Mikkola K, Ståhls G (2008) Morphological and molecular taxonomy of *Dendrolimus sibiricus* Chetverikov stat.rev. and allied lappet moths (Lepidoptera: Lasiocampidae), with description of a new species. *Entomologica Fennica* 19: 66–85.

Milevoj L, Maček J (1997) Roßkastanien-Miniermotte (*Cameraria ohridella*) in Slowenien. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes (Braunschweig)* 49: 14–15.

Moffat CB (1897) *Bupalus piniaria* in Ireland. *The Irish Naturalist* 6: 283.

Montagud Alario S (2004) *Paysandisia archon* (Burmeister, 1880) (Lepidoptera, Castniidae), nuevas localizaciones en la Península Ibérica y su gestión. *Boletín Sociedad Entomológica Aragonesa* 34: 237–246.

Montermini A (1985) Quel lepidottero vorace sempre in viaggio. *Terra e Vita* 34: 21.

Nash DR, Agassiz DJL, Godfray HCJ, Lawton JH (1995) The pattern of spread of invading species: two leaf-mining moths colonizing Great Britain. *Journal of Animal Ecology* 64: 225–233.

Nash S (2003) *Earias vittella* (Fabricius) (Lep.: Noctuidae) the first occurrence of wild-caught moths in Europe. *Entomologist's Record and Journal of Variation* 115: 187–188.

Naves C (1995) Een recente vondst van *Idaea inquinata* in Nederland (Lepidoptera: Geometridae). *Entomologische Berichten* 55: 5.

Neves VC, Fraga JC, Schäfer H, Vieira V, Sousa B, Borges PV (2001) The occurrence of the Monarch butterfly, *Danaus plexippus* L. in the Azores, with a brief review of its biology. *Arquipélago Life and Marine Sciences* 18A: 17–24.

Nieukerken van EJ, Lastuvka A, Lastuvka Z (2004) Annotated catalogue of the Nepticulidae and Opostegidae of the Iberian Peninsula. *SHILAP Revista de Lepidopterologia* 32: 211–260.

Nieukerken van EJ, Gielis C, Huisman KJ, Koster JC, Kuchlein JH, Wolf van der HW, Wolschrijn JB (1993) Nieuwe en interessante Microlepidoptera uit Nederland (Lepidoptera). *Nederlandse faunistische Mededelingen* 5: 47–62.

Noreika R (1998) *Phyllonorycter issikii* (Kumata) (Lepidoptera, Gracillariidae) in Lithuania. *Acta Zoologica Lituanica* 8: 34–37.

Nuss M (2010) Global Information System of Pyraloidea (Insecta: Lepidoptera). http://www.pyraloidea.org/globiz_start/index_start.html.

Nyst RH (2004) Quand l'Afrique fait du tourisme sous la forme de *Sceliodes laisalis* (Lepidoptera). *Phegea* 32: 147–148.

OEPP/EPPO (2005) *Tecia* (*Scrobipalpopsis*) *solanivora* (Lepidoptera, Gelechiidae). *Bulletin OEPP/EPPO Bulletin. Data sheets on quarantine pests* 35: 399–401.

Olivella E (2001) *Phyllonorycter robiniella* (Clemens, 1859) arriba a la península Ibérica (Lepidoptera: Gracillariidae). *Butlleti de la Societat Catalana de Lepidopterologia* 87: 35–38.

Opheim M, Fjeldså A (1983) The Lepidoptera of Norway. Check-List. Part IV. Tineoidea, Zygaenoidea, Cossoidea and Incurvariinae. Oslo: Norsk Lepidopterologisk Selskap, 25 pp.

Ortu S, Delrio G (1995) La minatrice serpentina degli agrumi in Italia: *Phyllocnistis citrella* Stainton (Lep.: Gracillariidae: Phyllocnistinae). *Informatore Fitopatologico* 3: 38–41.

Ostrauskas H, Taluntyte L (2004) Insects of stored plant products in Lithuania. *Ekologija* 4: 50–57.

Palionis A (1932) Beitrag zur Kenntnis der Lepidopterenfauna Litauens [Indėlis Lietuvos drugiams pažinti]. Kaunas: Lietuvos universitetas, 187 pp.

Palm E (1986) Nordeuropas pyralider. *Danmarks Dyreliv* 3: 1–287.

Paoli G (1922) Un lepidottero nuovo per la fauna italiana (*Laspeyresia molesta* Busck). *Bollettino della Società Entomologica Italiana* 54: 122–126.

Passos de Carvalho J, Corley MFV (1995) Additions to the Lepidoptera of Algarve, Portugal (Insecta: Lepidoptera). *SHILAP Revista de Lepidopterologia* 23: 191–230.

Pelham-Clinton EC (1985) Tineidae. In: Heath J and Emmet AM (Eds) *The Moths and Butterflies of Great Britain and Ireland. Vol. 2. Cossidae-Heliodinidae*. Colchester: Harley Books, 152–207.

Péré C, Augustin S, Rumen T, Peng L-H, Turlings TCJ, Kenis M (2009) Species richness and abundance of native leaf miners are affected by the presence of the invasive horse-chestnut leaf miner. *Biological Invasions* DOI 10.1007/s10530–009–9518–0

Peterson NA, Nilssen AC (2004) Late autumn eclosion in the winter moth *Operophtera brumata*: compromise of selective forces in life-cycle timing. *Ecological Entomology* 23: 417–426.

Petersen W (1924) Lepidopteren-Fauna von Estland (Eesti). Talinn: Bildungsministerium der Freistaates Eesti, 589 pp.

Petralia L (1949) Contributo alle maggiori conoscenze sulla biologia della Tignola delle patate (*Gnorimoschema* (*Phthorimaea*) *operculella* Zell.). *Bollettino dell'Associazione Romana di Entomologia* 4: 21–28.

Pittaway AR (1993) The Hawkmoths of the Western Palaearctic. London & Colchester: Harley Books in association with the Natural History Museum, London, 240 pp.

Pittaway AR (2008) Saturniidae of Europe. http://tpittaway.tripod.com/silk/a_yam.htm.

Poltavsky AN, Artokhin KS (2006) *Tarachidia candefacta* (Lepidoptera: Noctuidae) in the south of European Russia. *Phegea* 34: 41–44.

Posenato G, Girolami V, Zangheri S (1997) La minatrice americana, un nuovo fillominatore della vite. *L'Informatore Agrario* 15: 75–77.

Povolny D (1996) Gelechiidae, Gnorimoschemini. Stenstrup: Apollo Books, 380 pp.

Prinz J (1907) Bericht der Sektion für Lepidopterologie. Versammlung am 4. Januar 1907. *Verhandlungen der kaiserlich-königlichen zoologischen-botanischen Gesellschaft in Wien* 57: 27–33.

Quacchia A, Ferracini C, Bonelli S, Balletto E, Alma A (2008) Can the Geranium Bronze, *Cacyreus marshalli*, become a threat for European biodiversity? *Biodiversity and Conservation* 17: 1429–1437.

Quajat E (1904) Dei bozzoli più pregevoli che preparano i lepidotteri setiferi. Padova-Verona: Fratelli Drucker, 170 pp.

Rebel H (1901) [Microlepidoptera section in «Famil. Papilionidae-Hepialidae»]. In: Staudinger O and Rebel H (Eds) Catalog der Lepidopteren des palaearctischen Faunengebietes. Berlin: Friendlander & Sohn. 411 pp.262.

Rebel H (1903) Studien über die Lepidopterenfauna der Balkänlander I Tail Bulgarien und Ostrumelien. *Annalen des Kaiserlich-Königlichen Naturhistorischen Hofmuseums, Wien* 18: 123–347.

Reid J (2008) Raspberry Clearwing moth *Pennisetia hylaeformis* (Laspeyres, 1801) in South Cambridgeshire and North Hertfordshire. *Entomologist's Record and Journal of Variation* 120: 165–170.

Reiprich A (1980) K bionómii rúrkovčeka Coleophora spiraeella Rebel, 1916 (Lepidoptera Coleophoridae). *Zprávy Československé Společnosti Entomologické Při ČSAV* 16: 98–100.

Reiprich A, Janovský M (1981) Prehľad nových a pozoruhodných druhov motýľov zo Slovenska z rokov 1973–1977 (Ďalšie poznámky k Prodromu lepidopter Slovenska - Hrubý 1964). *Zprávy Československé Společnosti Entomologické Při ČSAV* 17: 103–113.

Reiprich A (1989) Prírastky motýlej fauny na Slovensku v období rokov 1985–1988, 4.časť. *Zprávy Československé Společnosti Entomologické Při ČSAV* 1: 6–11.

Reiprich A, Okáli I (1989) Dodatky k Prodromu Lepidopter Slovenska zvazok. Bratislava: Veda, 109 pp.

Reiprich A (1990) Prírastky motýlej fauny na Slovensku v roku 1989. *Zprávy Československé Společnosti Entomologické Při ČSAV* 2: 1–7.

Reiprich A (1991) Prírastky motýlej fauny na Slovensku v roku 1990. *Zprávy Československé Společnosti Entomologické Při ČSAV* 3: 20–23.

Reiprich A (1992) Prírastky motýlej fauny na Slovensku v roku 1991. *Zprávy Československé Společnosti Entomologické Při ČSAV* 4: 7–14.

Rennwald K (2008) Ein Neubürger in Deutschland an Buchsbaum - Der Buchsbaumzünsler *Glyphodes perspectalis* [http://www.klaus-rennwald.de/neubuerger/index.html].

Reynaud P, Chapin E, Hostachy B, Drescher J, Blanchon F, Vidal C (2002) Deux nouveaux papillons à l'assaut des palmiers de la Côte d'Azur. *Paysandisia archon* et *Pseudarenipses insularum*. *Phytoma. La Défense des Végétaux* 550: 18–21.

Rezbanyai-Reser L (1983) Über *Caradrina*-Arten, insbesondere über *C. ingrata* Staudinger 1897, eine für die Schweiz und für Mitteleuropa neue mediterrane Art (Lep., Noctuidae). *Entomologische Berichte Luzern* 10: 99–109.

Rezbanyai-Reser L (1991) *Hyphantria cunea* Drury, 1773, und *Noctua tirrenica* Biebinger, Speidel & Hanigk, 1983, im Südtessin, neu für die Schweiz (Lep.: Arctiidae, Noctuidae). *Entomologische Berichte Luzern* 26: 94–96, 135–152.

Rezbanyai-Reser L, Kádár M, Petrányi G, Kocsy G (2004) *Report Euro-moth-nights 2004*. http://euromothnights.uw.hu/1emn_2004_bilanz_english.pdf .

Rezbanyai-Reser L, Kádár M, Schreiber H (2005) Report Euro-moth-nights. http://euromothnights.uw.hu/2emn_2005_bilanz_english.pdf.

Riedl T (1990) Sur quelques Gelechioidea conservés au Musée Zoologique de Copenhague (Lepidoptera) (Partie II). *Nota Lepidopterologica* 12: 319–327.

Robinson GS, Nielsen ES (1989) Tineid genera of Australia. Melbourne: CSIRO PUBLISHING, 344 pp.

Robinson GS, Ackery PR, Kitching IJ, Beccaloni GW, Hernández LM (2010) *HOSTS – a Database of the World's Lepidopteran Hostplants.* http://www.nhm.ac.uk/researchcuration/research/projects/hostplants/.

Roche J (1982) *Zophodia convolutella* (Huebner) (Lep.: Pyralidae) new to Britain. *Entomologist's Record and Journal of Variation* 96: 117.

Roesler RU (1973) Phycitinae. 1. Teilband: Trifine Acrobasiina. In: Amsel HG, Gregor F and Reisser H (eds) *Microlepidoptera Palaearctica*. Vienna and Munich: Verlag Georg Fromme & Co., 752.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Roques, A, Auger-Rozenberg, MA, Boivins, S (2006) A lack of native congeners may limit colonization of introduced conifers by indigenous insects in Europe. *Canadian Journal of Forest Research* 36: 299–313.

Roques A, Rabitsch W, Rasplus J, Lopez-Vaamonde C, Nentwig W, Kenis M (2008) Alien terrestrial invertebrates of Europe. In: Nentwig W, Hulme P, Pysek P and Vila M (Eds) *Handbook of Alien Species in Europe*. Dordrecht: Springer-Verlag, 63–79.

Russo G (1939) Contributo alla conoscenza degli insetti dannosi al cotone nell'Africa orientale italiana. I Lepidotteri. *Bollettino Regio Laboratorio di Entomologia Agraria. Portici* 3: 105–220.

Sammut P (2000) Kullana Kulturali 12 - Il-Lepidoptera. Malta: Pubblikazzjonijiet Indipendenza, 246 pp.

Sammut P (2003) *Arenipses sabella* (Hampson, 1901) and *Myelois circumvoluta* (Fourcroy, 1785) (Insecta: Lepidoptera: Pyralidae) new to the Lepidopterofauna of the Maltese Islands. *Central Mediterranean Naturalist* 4: 49–50.

Sammut P (2005) The correct identity of three Pyralidae moths from the Maltese islands (Lepidoptera Pyralidae) *SHILAP Revista de Lepidopterologia* 33: 235–238.

Sammut P (2007) *Cacyreus marshalli* Butler, [1898] reaches the Maltese Islands (Lepidoptera, Lycaenidae). *SHILAP Revista de Lepidopterologia* 35: 317–319.

Sarto i Monteys V (1992) Spread of the Southern African Lycaenid butterfly, *Cacyreus marshalli* Butler, 1898, (LEP: Lycaenidae) in the Balearic Archipelago (Spain) and considerations on its likely introduction to continental Europe. *Journal of Research on the Lepidoptera* 31: 24–34.

Sarto i Monteys V (2002) The discovery, description and taxonomy of *Paysandisia archon* (Burmeister, 1880), a castniid species recently found in southwestern Europe (Castniidae). *Nota Lepidopterologica* 25: 3–16.

Savela M (2010) http://ftp.funet.fi/pub/sci/bio/life/warp/album-Silvonen-3.html.

Šefrová H (1998) Výskyt klíněnky hlohyňové (*Phyllonorycter leucographellus*) v České republice. *Plant Protection Science* 34: 112–113.

Šefrová H (1999) On larval morphology, biology and distribution of *Phyllonorycter leucographellus* (Zeller) (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 47: 57–63.

Šefrová H (2001) *Phyllonorycter platani* (Staudinger) - a review of its dispersal history in Europe (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 49: 71–75.

Šefrová H, Laštůvka Z (2001) Dispersal of the horse-chestnut leafminer, *Cameraria ohridella* Deschka & Dimić, 1986, in Europe: its course, ways and causes (Lepidoptera: Gracillariidae). *Entomologische Zeitschrift Stuttgart* 111: 194–198.

Šefrová H (2002) *Phyllonorycter issikii* (Kumata, 1963) - bionomics, ecological impact and spread in Europe (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 50: 99–104.

Šefrová H (2002) *Phyllonorycter robiniella* (Clemens, 1859) - egg, larva, bionomics and its spread in Europe (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 50: 7–12.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Seljak G (1995) *Phyllonorycter robiniella* (Clemens), še en nov listni zavrtač robinije v Sloveniji [*Phyllonorycter robiniella* (Clemens), an other new leaf miner of *Robinia* in Slovenia]. *Gozdarski vestnik* 53: 78–82.

Seljak G (2005) Kačasti listni zavrtač vinske trte (*Phyllocnistis vitegenella* Clemens) že v Sloveniji [*Phyllocnistis vitegenella* Clemens) occurring also in Slovenia]. *SAD, Revija za Sadjarstvo, Vinogradništvo in Vinarstv* 16: 13–14.

Seymour PR, Kilby LJ (1978) Insects and other invertebrates intercepted in check inspections of imported material in England & Wales during 1978. *Report of the MAFF Plant Pathology Laboratory* 10: 1–54.

Shchurov VI (2004) The butterflies and moths fauna (Insecta, Lepidoptera) of Taman Peninsula. *Ekologicheskie problemy Tamanskogo poluostrova*. Krasnodar: Kuban State University, 53–68.

Siloaho R (2008) *Bucculatrix chrysanthemella* Rebel 1896 (Bucculatricidae) - Suomesta ja Manner - Euroopasta aiemmin havaitsematta jäänyt töyhtökoilaji. *Baptria* 4: 142–143.

Silvestri F (1943) *Compendio di Entomologia applicata (agraria, forestale, medica, veterinaria)*. Portici: Della Torre, 699 pp.

Sinev S (2007) New and little known species of gray moths (Lepidoptera, Gelechioidea, Blastobasidae) from Eurasia. *Entomological Review* 87: 1064–1073.

Sitek J (2003) Faunistic records from the Czech Republic – 169. Lepidoptera: Tineidae, Gelechiidae, Tortricidae. 2 pp. *Klapalekiana* 39: 137–138.

Skala H (1936) Minen aus Mittel- und Südeuropa. *Zeitschrift des Österreichischen Entomologen-Vereins* 21: 78–79.

Skala H (1937) Minen aus Mittel- und Südeuropa. *Zeitschrift des Österreichischen Entomologen-Vereins* 22: 10–11; 18–19.

Škerlavaj V, Munda A (1999) *Argyresthia thuiella* Packard - a new pest of Thuja in Slovenia. *Zbornik predavanj in referatov 4. slovenskega posvetovanja o varstvu rastlin v Portorožu od 3. do 4. Marca 1999*, *Ljubljana*: Društvo za varstvo rastlin Slovenije, p. 451.

Skinner B (2009) Colour identification guide to Moths of the British Isles. Stenstrup: Apollo Books, 325 pp.

Skou P (1986) The Geometroid moths of North Europe (Lepidoptera, Drepanidae and Geometridae). Leiden/Copenhagen: E.J. Brill/Scandinavian Science Press, 348 pp.

Snellen PCT (1898) Aanteekeningen over Nederlandsche Lepidoptera. 3. *Tijdschrift voor Entomologie* 40: 278–367.

Speidel W, Nieukerken van EJ, Honey MR, Koster SJC (2007) The exotic pyraloid moth *Diplopseustis pereresalis* (Walker) in the west Palaearctic region (Crambidae, Spilomelinae). *Nota Lepidopterologica* 29: 185–192

Speiser P (1903) Die Schmetterlingsfauna der Prowinzen Ost – und Westpreussen. *Beitrage zur Naturkunde Preussens* 9: 1–148.

Stanev M, Kaitazov A (1962) Studies on the biology, ecology and means for the control of the potato-moth *Gnorimoschema (Phthorimaea) operculella* Zeller in Bulgaria. *Bulletin of the Research Institute of Plant Protection* 3: 49–89.

Starý B (1936) Studie o minujících motýlech na Slovensku. *Příroda* 29: 1–3, 90–95.

Sterneck J, Zimmermann F (1933) *Prodromus der Schmetterlingsfauna Böhmens. II. Teil: Microlepidoptera*. Karlsbad: Selbstverlag, 168 pp.

Stigter H, Frankenhuyzen Av (1991) *Phyllonorycter leucographella*, een voor Nederland nieuwe bladmineerder (Lepidoptera: Gracillariidae). *Entomologische Berichten* 51: 129–135.

Stigter H, Frankenhuyzen Av, Moraal LG (2000) De paardenkastanjemineermot, *Cameraria ohridella*, een nieuwe bladmineerder voor Nederland (Lepidoptera: Gracillariidae). *Entomologische Berichten* 60: 159–163.

Streito J-C, Martinez M (2005) Nouveaux ravageurs, 41 espèces depuis 2000. point sur les introductions d'insectes ravageurs d'importance agronomique de janvier 2000 à juin 2005. *Phytoma, la défense des végétaux* 586: 16–20.

Strygina SP, Shutova NN (1966) *Vostochnaya plodozhorka* (The Oriental fruit moth). *Zashchita Rastenii* 8: 26.

Šumpich J, Míkát M, Maršík L, Dufek T, Marek J, Elsner V (2007) Faunistic records from the Czech Republic - 239. *Klapalekiana* 43: 215–220.

Surányi P (1946) A féher medveszövőlepke és életmódja. *Folia Entomologica Hungarica* 1: 87–90.

Svensson I (1977) Förändringar i Sveriges storfjärilfauna en tredje tioårsperiod (Lepidoptera). *Entomologisk Tidskrift* 98: 113–122.

Svensson I (1986) Anmärkningsvärda fynd av Microlepidoptera i Sverige 1985. *Entomologisk Tidskrift* 107: 71–79.

Svensson I (1992) Anmärkningsvärda fynd av Microlepidoptera i Sverige 1991. *Entomologisk Tidskrift* 113: 36–41.

Svensson I (2006) Nordens vecklare (The Nordic Tortricidae): (Lepidoptera, Tortricidae). Lund Entomologiska sällskapet i Lund, 349 pp.

Svensson I (2007) Anmärkningsvärda fynd av småfjärilar (Microlepidoptera) i Sverige 2006. *Entomologisk Tidskrift* 128: 43–57.

Tapia-Domínguez P (1982) *Danaus chrysippus* (L.) y *D. plexippus* (L.) en la provincia de Málaga. *SHILAP Revista de Lepidopterologia* 10: 274.

Tarmann GM (1998) Die Weinzygaene *Theresimima ampellophaga* (BAYLE-BARELLE 1808) (Lepidoptera, Zygaenidae, Procridinae). Kehrt ein verschwundener Weinschädling zurück? *Stapfia* 55: 57–84.

Tautel C (2008) *Araeopteron ecphaea* (Hampson, 1914) désormais présent en France continentale (Lep. Noctuidae). *Oreina* 2: 10.

Thomas JA, Simcox DJ, Clarke RT (2009) Successful conservation of a threatened *Maculinea* butterfly. *Science* 325: 80–83.

Thygesen T (1963) Importerede stiklinger af nelliker og chrysanthemum - plantepatalogisk set. *Gartner Tidende* 79: 2.

Thygesen T, Esbjerg P, Eiberg H (1965) Dynamics of the western spruce budworm (Lepidoptera: Tortricidae) *Hilgardia* 36: 391.

Tokár Z, Slamka F, Pastorális G (1999) New and interesting records of Lepidoptera from Slovakia in 1995–1997. *Entomofauna Carpathica* 11: 43–57.

Tokár Z, Richter I, Pastorális G, Slamka F (2002) New and interesting records of Lepidoptera of Slovakia from the years 1998–2001. *Entomofauna Carpathica* 14: 1–11.

Tomov R (2003) *Phyllonorycter robiniella* (Clemens, 1859) (Lepidoptera, Gracillariidae), a new pest on black locust *Robinia pseudoacacia* L. In Bulgaria. *Proceedings scientific papers, The 50th anniversary of University of Forestry*, *Sofia*, p. 105–107.

Torp R (1987) Ny dansk spinder: *Hyphantria cunea* Drury f. textor Harr. *Lepidoptera* 5: 83–86.

Torstenius S, Lindmark H (2000) *Synanthedon andrenaeformis* (Laspeyres 1801), Lepidoptera: Sesiidae, en för Sverige ny glasvinge. *Entomologisk Tidskrift* 121: 21–22.

Trematerra P (1988) *Paramyelois transitella* (Walker) lepidottero americano presente nelle noci importate dalla California. *Informatore Fitopatologico* 38: 51–55.

Trematerra P, Zilli A, Valentini V, Mazzei P (1997) *Cacyreus marshalli* un lepidottero sudafricano dannoso ai gerani in Italia. *Informatore fitopatologico* 7: 2–6.

Troukens W (1991) *Cacyreus marshalli* Butler, 1898 aangetroffen in België (Lepidoptera: Lycaenidae). *Phegea* 19: 129–131.

Tschorbadjiew P (1930) Saobschtenie vurhu nyakoi vredni nasekomi. *Izvestiya na Balgarskoto entomologichesko druzestvo* 5: 35–37.

Tzalev M (1979) Po-golyamo vnimanie na borbata s iztochniya plodov tchervey. *Plant protection* 6: 5.

Ulmer G, Strand E, Horn W (1918) Über W. Horns Litauische entomologische Kriegsausbente 1916 (besonders Trichoptera, Ephemeroptera, Lepidoptera und Hymenoptera). *Entomologische Mitteilungen* 7: 160–161.

Urbaneja A, Vercher R, Navarro V, García Marí F, Porcuna JL (2007) La polilla del tomate, *Tuta absoluta*. *Phytoma-España* 194: 16–23.

Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive horse-chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). *Molecular Ecology* 18: 3458–3470.

Valletta A (1949) Further moth captures from Malta. *Entomologist's Monthly Magazine* 85: 96.

Vane-Wright RI (1993) The Columbus hypothesis: an explanation for the dramatic 19th century range expansion of the monarch butterfly. In: Malcolm SB and Zalucki MP (Eds) *Biology and conservation of the monarch butterfly*. Los Angeles: Natural History Museum of Los Angeles County, 179–187.

Vargas HA (2007) *Megalorhipida leucodactyla* (Fabricius) (Lepidoptera: Pterophoridae): first distribution record from Chile and new host plant record. *Neotropical Entomology* 36: 476–477.

Vidano C (1970) Foglioline di *Robinia pseudoacacia* con mine di un Microlepidottero nuovo per l'Italia. *Apicoltore Moderno* 61: 1–2.

Vives Moreno A (2003) Una tribu, ocho géneros y dieciocho especies nuevos para la fauna española. *Ypsolophila cajaliella* Vives sp.n. para la ciencia en España (Insecta: Lepidoptera). *SHILAP Revista de Lepidopterologia* 31: 93–110.

Vlach V (1938) Příspěvek k soupisu českých Microlepidopter [Contribution to the list of the Czech Microlepidoptera]. *Ceskoslovenská spolecnost entomologická* 35: 29–30

Vrabec V, Heřman P (2006) *Elophila manilensis* (Hampson, 1917), p. . In: Mlíkovský J and Stýblo P (eds) *Alien species of fauna and flora of the Czech Republik*. Praha: ČSOP, 300–301.

Vuure Jv (1981) *Lithophane leautieri* (Boisduval), nieuw voor de Nederlandse fauna (Lep.: Noctuidae). *Entomologische Berichten* 41: 122–123.

Wagner D, Ferguson DC, Glaser JD (2003) *Sclerocona acutella* (Eversmann) (Crambidae: Pyraustinae), naturalized along the eastern seaboard. *Journal of Lepidopterists' Society* 57: 270–273.

Walsingham TdG (1910) Madeiran Tineina (Lepidoptera). *Entomologist's Monthly Magazine* 46: 257–259.

Waring P, Townsend M, Lewington R (2003) Field Guide to the Moths of Great Britain and Ireland. Gillingham, Dorset: British Wildlife Publishing, 432 pp.

Warren MS, Hill JK, Thomas JA, Asher J, Fox R, Huntley B, Roy DB, Telfer MG, Jeffcoate S, Harding P, Jeffcoate G, Willis SG, Greatorex-Davies JN, Moss D, Thomas CD (2001) Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature* 412: 65–69.

Weidner H (1971) Vorratsschädlinge, Bestimmungstabellen der Vorratsschädlinge und des Hausungeziefers Mitteleuropas. Stuttgart, New York: G. Fischer, 328 pp.

Whitebread SE (1990) *Phyllonorycter robiniella* (Clemens, 1859) in Europe (Lepidoptera, Gracillariidae). *Nota Lepidopterologica* 12: 344–353.

Wolff NL (1953) Sommerfuglelarver importeret med bananer. *Entomologiske Meddelelser* 26: 512–521.

Wolff NL (1969) *Sterrha inquinata* Scop. (Lep., Geometridae) i Danmark. *Indeks for Flora og Fauna 1890–1994,* 75: 31–32.

Wolff NL (1971) Lepidoptera. *The Zoology of Iceland* 3: 1–193.

Yaroshenko VA (1972) Biologiya amerikanskoi beloi babochki i mery bor'by s nei. *Nauchnye trudy Kubanskogo Universiteta* 151: 61–91.

Zagulajev AK (1982) The potato moth - *Phthorimaea operculella* Zll. (Lepidoptera, Gelechiidae). *Entomologicheskoe Obozrenie* 61: 817–820.

Zangheri S, Cavalloro R (1971) Sulla presenza in Italia di *Epichoristodes acerbella* (Walker) (Lepidoptera Tortricidae). *Bolletino della Società Entomologica Italiana* 103: 186–190.

Zilli A (1997) Lepidoptera. In: Zapparoli M (Ed) *Gli Insetti di Roma*. Roma: Fratelli Palombi Editori, 294–311.

Zolnir M (1977) Invertarizacija sladiscnih skodljivcev: porocilo za leto 1975 in koncno porocilo. Zalec: RSS, 27 pp.

Zverezomb-Zubowsky EV (1918) Kratkij otchet o deyatel'nosti Donskogo byuro po bor'be s vreditelyami sel'skokhozyaistvennykh rastenij v 1917 godu. *Rostov-na-Donu*: 1–36.

Table 11.1. List and characteristics of the lepidopteran species alien *to* Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 01/06/2009

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries	Alien Habitat	Hosts	References
Arctiidae								
Hyphantria cunea (Drury, 1773)	A	Phyto-phagous	North America	1949, YU	AL, AT, BA, BG, CH, CZ, DE, DK, EE, FR, DE, GR, HR, HU, IT, LT, MD, ME, MK, PL, RO, RS, RU, SI, SK, GB	G5, I1, I2G	Polyphagous on deciduous trees (*Acer negundo, Populus, Morus, Prunus, Juglans*)	Buszko and Nowacki (2000), Essl and Rabitsch (2002), Gaedike and Heinicke (1999), Huemer and Rabitsch (2002), Ippolito and Parenzan (1981), Janežič (1968), Karsholt and Nielsen (1998), Luig and Kesküla (1995), Montermini (1985), Rezbanyai-Reser (1991), Šefrová and Laštůvka (2005), Yaroshenko (1972), Surányi (1946), Torp (1987)
Agonoxenidae								
Haplochrois theae (Kusnezov, 1916)	A	Phyto-phagous	Asia	1915, RU	RU	I1	*Thea, Camellia*	Demokidov (1916), Koster and Sinev (2003)
Blastobasidae								
Blastobasis adustella Walsingham, 1894	A	Detriti-vorous	Africa, Macaronesia (PT-MAD)	1902, IE	BE, FR, GB, IE, NL	G5, I2, J6	Decaying vegetal material	Aguiar and Karsholt (2006), De Prins et al. (2009), Karsholt and Sinev (2004)
Blastobasis decolorella (Wollaston, 1858)	A	Detriti-vorous	Africa, Macaronesia (PT-MAD)	1946, PT	PT	F5, G5, I2, J1, J6	Wide variety of foodstuffs, including leaf-litter, vegetation, and stored products	Corley et al. (2006), Karsholt and Sinev (2004)
Blastobasis lacticolella Rebel, 1940	A	Detriti-vorous	Africa, Macaronesia (PT-MAD)	1946, GB	GB, IE	G5, I2, J6	Decaying vegetal material	Aguiar and Karsholt (2006), Karsholt and Sinev (2004)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Blastobasis maroccanella Amsel, 1952	A	Detriti-vorous	Africa, Macaronesia (PT-MAD)	1990, PT	ES, FR, PT	B, F5, G5, I2, J6	Decaying vegetal material	Passos de Carvalho and Corley (1995)
Blastobasis rebeli Karsholt & Sinev, 2004	A	Detriti-vorous	Africa, Macaronesia (PT-MAD)	1998, GB	GB	G5, I2, J6	Decaying vegetal material	Aguiar and Karsholt (2006), Karsholt and Sinev (2004)
Bucculatricidae								
Bucculatrix chrysanthemella (Rebel, 1896)	A	Phyto-phagous	Africa (Macaro-nesia)	2007, IT	FI, FR, IT	I2	*Argyranthemum frutescens*	Cocquempot and Nel (2009), Constanzi et al. (2008), Klimesch (1979)
Castniidae								
Paysandisia archon (Burmeister, 1879)	A	Phyto-phagous	Neotropics (South America)	c.1995, ES	CY, DK, ES, ES-BAL, FR, GR, GR-CRE, IT, IT-SIC, SI	I2, J100	Palm trees *(Phoenix* spp, *Thritrinax, Chamaerops, Livistona, Trachycarpus, Washingtonia).*	Aguilar et al. (2001), Colazza et al. (2005), Espinosa et al. (2003), Hollingsworth (2004)
Cosmopterigidae								
Anatrachyntis simplex (Walsingham, 1891)	A	Phyto-phagous	Asia-Tropical	1999, PT	CY, ES, GB, PT	J1	Polyphagous, cotton, pomegranate fruits	Heckford (2004), Koster and Sinev (2003)
Ascalenia acaciella Chrétien, 1915	A	Phyto-phagous	Africa	2001, MT	MT	I2	*Acacia*	Koster and Sammut (2006)
Bifascioides leucomelanellus (Rebel, 1917)	A	Phyto-phagous	Africa	2004, MT	MT	I2	*Acacia*	Koster and Sammut (2006)
Gelechiidae								
Coleotechnites piceaella (Kearfott, 1903)	A	Phyto-phagous	North America	1952, GB	AT, CZ, DE, FR, GB, HU, IT, SK	G3, G5, I2	*Picea*	Essl and Rabitsch (2002), Hill et al. (2005), Huemer and Rabitsch (2002), Reiprich (1991), Šumpich et al. (2007)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Pectinophora gossypiella (Saunders, 1844)	A	Phyto-phagous	Australasia	1935, IT	AL, BG, ES, GR, GR-CRE, IL, IT, IT-SIC	I1	Cotton	Karsholt and Nielsen (1986), Povolny (1996), Roll et al. (2007), Russo (1939)
Phthorimaea operculella (Zeller, 1873)	A	Phyto-phagous	Neotropics (South America)	1899, MT	AL, AT, BE, BG, DK, ES, GB, GR, HU, IL, IT, IT-SAR, IT-SIC, MK, MT, NL, PT, PT-AZO, PT-MAD, RU, SE, SI	I1, J1	Potato, tobacco and other Solanaceae, stored products and fields	Aastrup (1969), Bentinck (1963), Borg (1899), García Mercet (1926), Huemer and Rabitsch (2002), Janežič (1951), Karsholt and Sinev (2004), Mendes (1910), Petralia (1949), Roll et al. (2007), Stanev and Kaitazov (1962), Zagulajev (1982)
Sitotroga cerealella (Olivier, 1789)	A	Grain feeder	Australasia	1790, DE?	AL, AT, BE, BG, BY, CH, CZ, DE, DK, ES, FR, GB, GR, HR, HU, IS, IT, IT-SAR, IT-SIC, LT, MK, MT, NL, NO, PL, PT, PT-AZO), RO, RU, RS, SE, SI, SK, GB	J1	Stored products	Borg (1932), Dei (1871), Glavendekić et al. (2005), Hrubý (1964), Huemer and Rabitsch (2002), Ivinskis (1993), Janežič (1951), Karsholt and Nielsen (1976), Karsholt and Vieira (2005), Lindeman (1880), Mehl (1977), Ostrauskas and Taluntyte (2004), Šefrová and Laštůvka (2005), Snellen (1898), Tschorbadjiew (1930)
Tecia solanivora (Povolny, 1973)	A	Phyto-phagous	Neotropics	1999, ES-CAN	ES-CAN	I1, J1	Potato	OEPP/EPPO (2005)
Tuta absoluta (Meyrick, 1917)	A	Phyto-phagous	Neotropics	2006, ES	AL, BG, CH, ES, ES-BAL, FR, FR-COR, IT, IT-SIC, LT, MT, SI	I1, J1	Tomato	Harizanova et al. (2009), Ostrauskas and Ivinskis (2010), Urbaneja et al. (2007)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries	Alien Habitat	Hosts	References
Geometridae								
Pseudocoremia suavis Butler, 1879	A	Phyto-phagous	Australasia (New Zealand)	2007, GB	GB	G3, X25	*Nothofagus* spp., *Podocarpus*, *Kunzea ericoides*, *Pinus* spp. (mainly *P. radiata)* and *Pseudotsuga menziesii*	James (2008), Skinner (2009)
Gracillariidae								
Caloptilia azaleella (Brants, 1913)	A	Phyto-phagous	E Asia	1920, NE	AT, BE, CH, CZ, DE, DK, ES, FR, GB, IT, NL, NO, PL, PT, PT-MAD, RU, SE, SI, SK	I2, J100	*Rhododendron*	Aguiar and Karsholt (2006), Brants (1913), Della Beffa (1931), Emmet et al. (1985), Gomboc (2003), Huemer and Rabitsch (2002), Jørgensen (1982), Lhomme (1946–1963), Opheim and Fjeldså (1983), Šefrová and Laštůvka (2005), Starý (1936)
Parectopa robiniella Clemens, 1863	A	Phyto-phagous	North America	1970, IT	AT, BG, CH, CZ, DE, ES, FR, HR, HU, IT, LT, MK, PL, RO, RS, SI, SK, GB	I2, FA, G1, G5	*Robinia*	Buszko and Nowacki (2000), Huemer and Rabitsch (2002), Ivinskis and Rimsaite (2008), Maček (1982), Marek et al. (1991), Olivella (2001), Vidano (1970)
Phyllocnistis citrella (Stainton, 1856)	A	Phyto-phagous	Asia	1993, ES	AL, CY, ES, FR, GR, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, RS	I2	*Citrus*	de Carvalho and Aguiar (1997), Corley et al. (2000), Garijo and Garcia (1994), Karsholt and Vieira (2005), Mihelakis (1997), Ortu and Delrio (1995), Roll et al. (2007)
Phyllocnistis vitegenella Clemens, 1859	A	Phyto-phagous	North America	1997, IT	AL, IT, SI	I1	*Vitis*	Posenato et al. (1997), Seljak (2005)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Phyllonorycter issikii (Kumata, 1963)	A	Phyto-phagous	E Asia	1985, RU	AT, BG, BY, CZ, DE, EE, FI, HR, HU, LT, PL, RO, RU, SI, SK, GB	I2, FA, G1, G5	*Tilia*	Bednova and Belov (1999), Buszko and Nowacki (2000), Ermolaev and Motoshkova (2008), Gomboc et al. (in press), Huemer and Rabitsch (2002), Noreika (1998), Šefrová (2002a), Tokár et al. (2002)
Phyllonorycter leucographella (Zeller, 1850)	A	Phyto-phagous	SW Asia	1850, IT	AT, BE, BG, CH, DE, CZ, DK, FR, GB, GR, HR, HU, IT, NL, PL, RS, SE, SI, SK	I2, FB	Rosaceous bushes, mainly firethorn (*Pyracantha*)	Baraniak and Walczak (2000), Buhl et al. (1994), Csoka (2001), De Prins (1994), Glavendekić et al. (2005), Huemer and Rabitsch (2002), Maček (1976), Šefrová (1998), Šefrová (1999), Stigter and Frankenhuyzen (1991)
Phyllonorycter platani (Staudinger, 1870)	C	Phyto-phagous	Cryptogenic	1870, IT	AL, AT, BE, BG, CH, CZ, DE, DK, ES, FR, FR-COR, GB, GR, HR, HU, IL, IT, IT-SAR, IT-SIC, MK, NL, PL, PT, PT-MAD, SE, SI, SK, GB	I2, X11, FA, G5	*Platanus*	Aguiar and Karsholt (2006), Baeta-Neves (1945), Frankenhuyzen (1983), Huemer and Rabitsch (2002), Janmoulle (1954), Maček (1968), Roll et al. (2007), Šefrová (2001), Skala (1936), Skala (1937)
Phyllonorycter robiniella (Clemens, 1859)	A	Phyto-phagous	North America	1983, CH	AL, AT, BE, BG, CH, CZ, DE, DK, ES, FR, HR, HU, IT, LT, NL, PL, RO, RS, SI, SK, GB	I2, X11, FA, G1, G5	*Robinia*	Bolchi Serini and Trematerra (1989), Buhl et al. (2005), Buszko and Nowacki (2000), De Prins and Groenen (2001), Glavendekić et al. (2005), Huemer and Rabitsch (2002), Huisman et al. (2003), Ivinskis and Rimsaite (2008), Olivella (2001), Šefrová (2002b), Seljak (1995), Tomov (2003), Whitebread (1990)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Lycaenidae								
Cacyreus marshalli Butler, 1898	A	Phyto-phagous	Africa	1987, ES-BAL	BE, CH, DE, ES, ES-BAL, FR, FR-COR, GB, IT, IT-SAR, IT-SIC, MT, PT	I2, J1	*Pelargonium*	Aistleitner (2003), Fuentes Garcia (1997), Sammut (2007), Sarto i Monteys (1992), Trematerra et al. (1997), Troukens (1991), Zilli (1997)
Noctuidae								
Acontia (Emmelia) candefacta (Hübner, 1831) (according to Fauna Europaea)	A	Phyto-phagous	North America	1967, RU,	RU, GB	I1, J6	Ragweed (*Ambrosia* spp.)	Poltavsky and Artokhin (2006), Rezbanyai-Reser et al. (2005), Shchurov (2004)
Araeopteron ecphaea (Hampson, 1914)	A	Phyto-phagous	Africa	1987, GR/ES	FR, FR-COR, GR, ES, BAL		Unknown, a New Guinea species of *Ecphaea* feeds on legume pods	Rezbanyai-Reser et al. (2004), Robinson et al. (2010), Tautel (2008)
Callopistria maillardi (Guenée, 1862)	C	Phyto-phagous	Cryptogenic (Oriental, Australasia, Pacific and Africa)	1983, DE, DK	DE, DK	I1, I2	Ferns *(Adiantum, Lygodium, Nephrolepis, Plleaea)*	Bathon (1984), Buhl et al. (1985), Karsholt (1994)
Chrysodeixis acuta (Walker, 1858)	C	Phyto-phagous	Cryptogenic (Tropical/ Subtropical)	1998, AT	AT, ES, ES-CAN, FR, GB, IE, PT-MAD	I1, I2	Polyphagous: Tomato, cotton, soybean, banana, tobacco, *Citrus*	Aguiar and Karsholt (2006), Huemer and Rabitsch (2002)
Chrysodeixis eriosoma (Doubleday, 1843)	A	Phyto-phagous	Australasia	2002, DE	DE	I1,I2	Highly polyphagous, foliage and fruit of many field and vegetable crops, ornamentals and weeds: chickpeas, lucerne, maize, potato, sunflower, etc.	Geiter et al. (2001)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries	Alien Habitat	Hosts	References
Spodoptera litura (Fabricius, 1775)	A	Phyto-phagous	Asia-Tropical	1978, GB	AL, DE, GB	F5, F6, F8, I1, I2,J100	Highly polyphagous, crops and ornamentals	Seymour and Kilby (1978)
Nolidae								
Earias vittella (Fabricius, 1794)	A	Phyto-phagous	Asia	2003, ES	ES	I1, J6	Okra (*Abelmoschus esculentus*) pods, *Gossypium* and *Hibiscus*	Nash (2003)
Nymphalidae								
Danaus chrysippus (Linnaeus, 1758)	A	Phyto-phagous	Africa	1982, ES	ES, ES-CAN, GR, HR, IT-SIC	I1, I2, G, H	*Asclepias, Cynanchum acutum, Gomphocarpus fruticosus, Gossypium arboreum, Caralluma burchardii*	Baez (1998), Gómez de Aizpúrua (2004), Tapia-Domínguez (1982)
Danaus plexippus (Linnaeus, 1758)	A	Phyto-phagous	North America	1887, ES-CAN	ES, ES-CAN, PT, PT-AZO, PT-MAD	I1, I2, G, H	*Asclepias, Gomphocarpus fruticosus, Gossypium arboretum*	Baez (1998), Gómez de Aizpúrua (2004), Neves et al. (2001), Tapia-Domínguez (1982)
Oecophoridae								
Borkhausenia nefrax Hodges, 1974	A	Detriti-vorous	North America	1961, PL	ES, FR, NL, PL	J1	Decaying plant material	Buszko and Vives Moreno (1992), Kuchlein and van Lettow (1999)
Eratophyes amasiella (Herrich-Schäffer, 1854)	A	Detriti-vorous	Asia (Turkey)	1972, NL	BE, DE, DK, NL, SE	J1	Decaying wood	Buhl et al. (1991), Buhl et al. (2004), De Prins (2007), Svensson (2007)
Neomariania rebeli (Walsingham, 1894)	A	Phyto-phagous	Africa, Macaronesia (PT-MAD and ES-CAN)	1986, PT	PT	B	Unknown	Riedl (1990)
Tachystola acroxantha (Meyrick, 1885)	A	Detriti-vorous	Australasia	1908, GB	GB	I2	Withered leaves, leaf-litter	Hind (2000)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Pterophoridae								
*Lantanophaga pusillidact*ylus (Walker, 1864)	C	Phyto-phagous	Cryptogenic (tropical, type locality, Jamaica)	1973, PT-MAD	ES, IT, PT-AZO, PT-MAD	I2	*Lantana camara*	Aguiar and Karsholt (2006), Bella and Marchese (2007), Kimber (2008)
Megalorhipida leucodactylus (Fabricius, 1794)	C	Phyto-phagous	Cryptogenic (tropical , type locality Virgin Islands)	1967, IT-SIC	IL, IT-SIC	F5,F8, I2	*Acacia neovernicosa*, *Mimosa tenuiflora* (Fabaceae), *Boerhavia diffusa*, *B. coccinea*, *B. chinensis*, *B. repens*, *Commicarpus tuberosus* *Okenia hypogaea* (Nyctaginaceae), *Amaranthus* (Amaranthaceae), *Scaevola frutescens* (Goodeniaceae),*Tessaria absinthioides* (Asteraceae).	Bella and Ferrauo (2005), Gielis (1996)
Pyralidae + Crambidae								
Agassiziella angulipennis (Hampson, 1891)	A	Phyto-phagous	Asia	1977, GB	GB, NL	J1, J100	Aquatic water plants	Goater (1986), Goater et al. (2005)
Arenipses sabella Hampson, 1901	A	Phyto-phagous	Africa (North Africa, Middle east)	1999, ES	ES, FR	I2	Palm trees (*Phoenix* spp)	Asselbergs (1999), Streito and Martinez (2005)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries	Alien Habitat	Hosts	References
Cadra cautella (Walker, 1863)	C	Phyto-phagous	Cryptogenic (type locality: India)	1900,?	AL, AT, BE, BG, CH, CY, CZ, DK, ES, FI, FR, FR-COR, DE, GB, GR, GR-CRE, HU, IE, IT, IT-SAR, IT-SIC, LV, LT, MT, NL, NO, PL, PT-AZO, PT-MAD, RO, RU, SE, SK	J1	Stored Products: dried fruits, nuts, grain	Aguiar and Karsholt (2006), von Andres (1916), Filipjev (1932), Huemer and Rabitsch (2002), Janmoulle (1965), Karsholt and Vieira (2005), Kenis (2005), Mehl (1977), Ostrauskas and Taluntyte (2004), Reiprich (1990), Šefrová and Laštůvka (2005), Paoli (1922)
Cadra figulilella (Gregson, 1871)	C	Detriti-vorous	Cryptogenic (type locality: Liverpool, England)	1871, GB	AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, ES, FR, FR-COR, GB, GR, GR-CRE, HR, HU, IE, IT, IT-SAR, IT-SIC, LT, LU, MK, MT, NO, PL, PT, PT-MAD, RO, RS, RU, SE, SI, SK, GB	J1	Dried fruits, raisins, figs	Carnelutti (1975), De Crombrugghe (1909), Goater (1986), Huemer and Rabitsch (2002), Kenis (2005), Reiprich and Okáli (1989), Roesler (1973), Šefrová and Laštůvka (2005)
Chilo suppressalis (Walker, 1863)	A	Phyto-phagous	Asia	1949, ES	ES, FR, FR-COR, RU	I1	Rice (leaves, stems)	Feron (1973), Gerasimov (1949)
Corcyra cephalonica (Stainton, 1866)	C	Detriti-vorous	Cryptogenic (Tropical, subtropical, (type locality, Great Britain)	1866, GB	AT, BE, BG, CH, CZ, DE, DK, ES, FR, GB, GR, IT, IT-SIC, LV, PL, PT, PT-AZO, RO, SE, GB	J1	Stored grain (Poaceae: e.g. rice)	Drensky (1930), Goater (1986), Huemer and Rabitsch (2002), Janmoulle (1938), Karsholt and Vieira (2005), Palm (1986), Šefrová and Laštůvka (2005), Silvestri (1943)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Diaphania perspectalis (Walker, 1859)	A	Phyto-phagous	Asia	2007, DE	CH, DE, FR, NL	I2	*Buxus*	Brua (2008), Rennwald (2008)
Diplopseustis perieresalis (Walker, 1859)	A	Phyto-phagous	Asia	2000, PT	BE, DK, ES, ES-BAL, MT, NL, PT	E3	*Carex*	Buhl (in press), Muus and Wullaert (2008), Speidel et al. (2007)
Elophila difflualis (Snellen, 1880)	A	Phyto-phagous	Asia	1978, DK	CZ, DK, FI, GB, NL	J1, J100	Aquatic plants	Buhl et al. (1982), Goater et al. (2005)
Elophila manilensis Hampson, 1917	A	Phyto-phagous	Asia-Tropical	1978, DK/GB	CZ, DK, GB	J1, J100	Aquatic plants	Buhl et al. (1982), Vrabec and Heřman (2006)
Elophila melagynalis (Agassiz, 1978)	A	Phyto-phagous	Asia-Tropical	1978, GB	GB	J100, J1	Aquatic plants	Agassiz (1978b)
Elophila obliteralis (Walker, 1859)	A	Phyto-phagous	North America	1968, GB	GB	J100	Waterlily	Goater (1986)
Ephestia elutella (Hübner, 1796)	C	Detriti-vorous	Cryptogenic (type locality, Germany)	1796, DE	AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR GB, GR, GR-CRE, HU, IE, IS, IT, IT-SAR, IT-SIC, LT, LV, MK, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, SI, SK	J1	Stored nuts, dried fruits, grain, etc.	Abafi-Aigner et al. (1896), Aguiar and Karsholt (2006), Caruana Gatto (1905), De Sélys-Longchamps (1844), Filipjev (1932), Huemer and Rabitsch (2002), Karsholt and Vieira (2005), Kenis (2005), Mehl (1977), Petersen (1924), Reid (2008), Šefrová and Laštůvka (2005), Speiser (1903), Paoli (1922)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries	Alien Habitat	Hosts	References
Ephestia kuehniella Zeller, 1879	C	Detriti-vorous	Cryptogenic (no type locality)	1879,?	AL, AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, GR-CRE, HU, IE, IS, IT, IT-SAR, IT-SIC, LT, LV, ME, MT, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK	J1	Stored nuts, dried fruits, grain, etc.	Aguiar and Karsholt (2006), Bolle (1921), Borg (1932), De Crombrugghe (1906), Glavendekić et al. (2005), Goater (1986), Hrubý (1964), Huemer and Rabitsch (2002), Janežič (1951), Karsholt and Vieira (2005), Kenis (2005), Mehl (1977), Palm (1986), Šefrová and Laštůvka (2005), Zverezomb-Zubowsky (1918)
Eustixia pupula Hübner, 1823	A	Phyto-phagous	North America	1997, GB	GB	I1	Cabbage, *Lepidium virginicum* (Cruciferae)	Budd and Goater (1998)
Herpetogramma licarsisalis (Walker, 1859)	C	Phyto-phagous	Cryptogenic (type locality: Malaysia: Sarawak, Old world tropics: Asia and Africa)	1994, CY	CY, ES, MT, PT, PT-MAD,SE	I2, E1	Monocots, turf grasses, pastures	Aguiar and Karsholt (2006), Karsholt and Vieira (2005), Sammut (2000)
Leucinodes orbonalis (Guenée, 1854)	A	Phyto-phagous	Africa	2004, BE	BE	I1	*Solanum melongena* (eggplant)	Nyst (2004)
Paralipsa gularis (Zeller, 1877)	A	Detriti-vorous	SE Asia (type locality: Japan)	1921	AT, BE, CH, CZ, DE, DK, FR, GB, HU, IT, IT-SIC, LV, NL, NO, SE	J1	Dry fruits, occasionally in imports of nuts for chocolate industry.	De Prins (1983), Giunchi (1957), Goater (1986), Huemer and Rabitsch (2002), Mariani (1941–1943), Mehl (1977), Palm (1986), Šefrová and Laštůvka (2005),

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Paramyelois transitella (Walker, 1863)	A	Phyto-phagous	North America	1870, AT	AT, IT	I2	*Juglans*	Huemer and Rabitsch (2002), Trematerra (1988)
Parapoynx bilinealis Snellen, 1876	A	Phyto-phagous	Asia-Tropical	1978, DK	DK, GB, SE	J100	Aquatic plants	Hancock (1984), Karsholt and Nielsen (1998)
Parapoynx crisonalis (Walker, 1859)	A	Phyto-phagous	Asia-Tropical	1979, GB	GB	J100	Aquatic plants	Goater (1986)
Parapoynx diminutalis Snellen, 1880	C	Phyto-phagous	Cryptogenic (Old world tropics: Asia and Africa)	1977, GB	AT, CZ, DK, FI, GB	J100	*Nymphaea*	Buhl et al. (1982), Goater (1986), Goater et al. (2005), Huemer and Rabitsch (2002)
Parapoynx fluctuosalis (Zeller, 1852)	C	Phyto-phagous	Cryptogenic (ES, Asia and Africa, type locality, Natal)	1979, GB	GB	J100	Aquatic plants	Goater (1986)
Parapoynx obscuralis Grote 1881	A	Phyto-phagous	North America	1967, GB	GB	J100	Aquatic plants	Goater (1986)
Parapoynx polydectalis Walker, 1859	A	Phyto-phagous	Australasia	1979, GB	GB, NL	J100	Aquatic plants	Goater et al. (2005)
Phycita diaphana (Staudinger, 1870)	C	Detriti-vorous	Cryptogenic (type locality: Spain, Malaga)	1870, ES, (2002, PT)	ES, GR, PT	I2,J6	*Ricinus communis*	Corley et al. (2000)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Plodia interpunctella (Hübner, 1813)	C	Detriti-vorous	Cryptogenic (no type locality)	1813, DE?	AL, AT, BE, BG, BY, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, GR-CRE, HU, IE, IS, IT, LV, LT, ME, MK, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, SI, SK, GB	J1	Stored plant products	Aguiar and Karsholt (2006), Borg (1932), Goater (1986), Hrubý (1964), Huemer and Rabitsch (2002), Ivinskis (1976), Karsholt and Vieira (2005), Kenis (2005), Martin (1991), Mehl (1977), Palm (1986), Rebel (1901), Šefrová and Laštůvka (2005), Zolnir (1977)
Pseudarenipses insularum Speidel & Schmitz, 1991	C	Phyto-phagous	Cryptogenic (type locality: Tenerife, Santa Cruz)	2002, FR, 2003, MT	ES, ES-CAN, FR, MT	I2	*Phoenix canariensis*	Reynaud et al. (2002), Sammut (2003), Sammut (2005)
Spoladea recurvalis (Fabricus, 1775)	A	Phyto-phagous	Tropics: Asia (type locality: India Orientali) South America and Africa	1968, NL (from Canaries)	BE, DK, IT, NL, PT-AZO, PT-MAD	I1, I2	*Beta vulgaris, Trianthema postulacastrum, Celosia* sp., *Chenopodium sp., Portulaca* sp., *Amaranthus* sp.	De Prins (2005), Karsholt and Vieira (2005), Nuss (2010)
Vitula edmandsii (Packard, 1865) ssp. *serratilineella* Ragonot, 1887	A	Detriti-vorous	North America	late 1940's, DE	DE, DK, FI, NO, SE	J	Honey, pollen, broods in bee nests	Kullberg and Mikkola (2001), Palm (1986), Svensson (1986), Weidner (1971)
Saturniidae								
Antheraea pernyi (Guérin-Méneville, 1855)	A	Phyto-phagous	Asia	1900, ES	ES, ES-BAL, HU	G1,G5, I2	*Quercus, Fagus, Betula, Aesculus*	Pittaway (2008)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Antheraea yamamai (Guérin-Méneville, 1861)	A	Phyto-phagous	Asia	1866-1868, SI	AT, BA, DE, HR, HU, IT, MK, RO, RS, SI	G1,G5, I2	*Quercus, Aesculus, Fagus, Castanea,* etc.	Blažič et al. (1995), Casale (1973), Glavendekić et al. (2005), Huemer and Rabitsch (2002), Pittaway (2008)
Samia cynthia (Drury, 1773)	A	Phyto-phagous	Asia	1854, IT	AL, AT, CH, DE, ES, FR, HR, IT, SI	I2, X24	*Ailanthus* and other deciduous trees	Huemer and Rabitsch (2002), Kenis (2005), Kollar(1854), Koster and Sinev (2003), Lepidopterologen Arbeitsgruppe (2000), Quajat (1904)
Tineidae								
Opogona omoscopa (Meyrick, 1893)	A	Phyto-phagous	Africa	1923, PT-MAD	DK, PT, PT-AZO, PT-MAD, SE	I1, I2J1	Stored products (grain, fruits), plants with mosses	Buhl et al. (1997), Corley (2005), Gaedike and Karsholt (2001), Karsholt and Vieira (2005)
Opogona sacchari (Bojer, 1856)	A	Phyto-phagous	C. Africa	1910, PT-MAD	AL, BE, BG, CH, CZ, DK, ES, ES-CAN, GB, GR, HU, IT, NL, PL, PT-AZO, PT-MAD	I2, J1, J100	*Dracaena, Strelitzia, Yucca, Alpinia, Begonia, Bougainvillea, Bromeliaceae,* Palms *(Chamaedorea* etc.), *Cordyline, Cycas, Hibiscus, Dieffenbachia, Poinsettia, Ficus, Gloxinia, Heliconia, Ippeastrum, Maranta, Philodendron, Sansevieria Saintpaulia,* banana plantations (*Musa acuminata*)	Aguiar and Karsholt (2006), Ciampolini (1973), Gaedike and Karsholt (2001), Jannone (1966), Karsholt and Vieira (2005), Sitek (2003), Walsingham (1910), Wolff (1953)

Family *Species*	Status	Regime	Native range	1st record in Europe and country	Invaded countries	Alien Habitat	Hosts	References
Praeacedes atomosella (Walker, 1863)	C	Detriti-vorous	Cryptogenic (type locality: Sierra Leone)	before 1979, PT-MAD	CY, MT, PT-AZO, PT-MAD	F5, F6, F7, I1, I2	*Pteridium*	Aguiar and Karsholt (2006), Gaedike and Karsholt (2001), Karsholt and Vieira (2005)
Psychoides filicivora (Meyrick, 1937)	A	Phyto-phagous	Asia (type locality: Ireland)	1909, IE	GB, IE	E5, F3, J100	Ferns (*Polystichum setiferum*, *Dryopteris filix-mas, Phyllitis scolopendrium*), often found indoors.	Beirne (1940), Gaedike and Karsholt (2001), Kimber (2008)
Tinea pallescentella Stainton, 1851	A	Detriti-vorous	Neotropics (South America)	1840, IE	AT, BE, CZ, DE, DK, FI, FR, GB, HU, IE, IT, LV, NL, NO, RO, RU, SE, SK	J1, J2, J6	Furs, dry fish	Heath and Emmet (1985), Karsholt and Nielsen (1998), Mehl (1977), Šefrová and Laštůvka (2005), Tokár et al. (1999), Vives Moreno (2003)
Tinea translucens Meyrick, 1917	A	Detriti-vorous	S Asia (type locality: Pakistan)	1856, UK	AL, AT, CY, CZ, DE, DK, ES, FR, GB, GR, GR-CRE, HR, HU, IS, IT, IT-SAR, IT-SIC, LV, LT, NO, PT, RO, RU, RS, SK, GB	J1	Stored products, clothes	Buhl et al. (1987), Ivinskis (1993), Opheim and Fjeldså (1983), Pelham-Clinton (1985), Reiprich (1992), Šefrová and Laštůvka (2005), Tokár et al. (2002)
Tineola bisselliella (Hummel, 1823)	C	Detriti-vorous	Cryptogenic (type locality, Europe)	1794, SE	AT, BE, BG, BY, CH, CZ, DK, EE, ES, FI, FR, FR-COR, DE, GB, HU, IS, IE, IT, LT, LV, NL, NO, PL, PT, RO, RU, SE, SI, SK, GB	J1, J2	Stored products, clothes	Drenowsky (1909), Hrubý (1964), Karsholt and Nielsen (1998), Mehl (1977), Mendes (1904), Mendes (1905), Palionis (1932), Peterson and Nilssen (2004), Šefrová and Laštůvka (2005)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Tortricidae								
Acleris undulana (Walsingham, 1900)	A	Phyto-phagous	Asia	1998, ES?	ES, FR	FA, G3, I2, X11	*Cedrus*	Vives Moreno (2003)
Clepsis peritana (Clemens, 1860)	A	Phyto-phagous	North America	1979, DE	DE,DK, GB, PT-MAD	I1, I2, J100	*Citrus, Euphorbia pulcherrima*, strawberries, and low herbaceous plants	Buhl et al. (1997), Hill et al. (2005)
Cryptophlebia leucotreta (Meyrick, 1927)	A	Phyto-phagous	Africa	1965, FI	IL,FI	I1, J100	*Citrus, Macadamia terniflora, Ricinus communis*, cotton	Bradley (1959), Hamburger et al. (2000), Karvonen (1983)
Dichelia cedricola (Diakonoff, 1974)	A	Phyto-phagous	Asia	POST-2001, FR	FR	G3, I2	*Cedrus*	Fabre et al. (2001)
Epichoristodes acerbella (Walker, 1864)	A	Phyto-phagous	Africa	1960, DK	DK, ES, FR, GB, IT, IT-SAR, IT-SIC, NO, RS	I2	Polyphagous, especially *Dianthus*	Costa Seglar and Vives Quadras (1976), Fjelddalen (1965), Glavendekić et al. (2005), Thygesen et al. (1965), Zangheri and Cavalloro (1971)
Epinotia algeriensis Chambon, 1990	A	Phyto-phagous	Africa	POST-1990, FR	FR	G3	*Cedrus*	Chambon et al. (1990)
Epinotia cedricida Diakonoff, 1969	A	Phyto-phagous	Africa	1968, FR	AT, BG, FR	G3, I2	*Cedrus*	Du Merle (1988), Huemer and Rabitsch (2002), Leclant (1969), Vives Moreno (2003)
Epiphyas postvittana (Walker, 1863)	A	Phyto-phagous	Australasia	1911, GB	GB, PT-AZO	I1, I2	Polyphagous *(Malus*, etc.)	Agassiz (1996a), Karsholt and Vieira (2005)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe and country**	**Invaded countries**	**Alien Habitat**	**Hosts**	**References**
Grapholita molesta (Busck, 1916)	A	Phyto-phagous	Asia	1920, SI	AL, AT, BA, BG, CH, CZ, DE, DK, ES, FR GR, HU, IT, IT-SAR, IT-SIC, LT, ME, MK, PT-AZO, RO, RS, RU, SI, SK, GB	I2	Rosaceae (*Prunus, Pyrus, Malus*)	Domínguez García-Tejero (1943), Dufrane (1960), Glavendekić et al. (2005), Hrdý and Krampl (1977), Huemer and Rabitsch (2002), Ivinskis (1993), Janežič (1951), Karsholt and Vieira (2005), Katsogiannos and Koveos (2001), Kyparissoudas (1989), Paoli (1922), Strygina and Shutova (1966), Tzalev (1979)
Lozotaenia cedrivora Chambon, 1990	A	Phyto-phagous	Africa	1968, FR	FR	G3, I2	*Cedrus*	Fabre (1997)
Yponomeutidae								
Argyresthia cupressella Walsingham, 1890	A	Phyto-phagous	North America	1997, GB	GB	I2	Cupressaceae (*Chamaecyparis, Cupressocyparis* , *Juniperus*)	Agassiz (1999)
Argyresthia thuiella (Packard, 1871)	A	Phyto-phagous	North America	1971, NL	AT, BE, BG, CH, CZ, DE, HU, NL, PL, SI, SK	I2, FA	*Thuja*, occasionally other Cupressaceae	De Prins (1983), Frankenhuyzen (1974), Huemer and Rabitsch (2002), Šefrová and Laštůvka (2005), Škerlavaj and Munda (1999), Tokár et al. (1999)
Prays citri (Millière, 1873)	A	Phyto-phagous	Asia	1877, IT	AL, DK, ES, FR, FR-COR, GR, GR-CRE, IL, IT, IT-SAR, IT-SIC, NL, PT, PT-AZO, PT-MAD	I2, J100	*Citrus*	Buhl et al. (2001), de Carvalho (1995), Franco et al. (2006), Karsholt and Vieira (2005), Liotta and Mineo (1963), Roll et al. (2007)
Prays peregrina Agassiz, 2007	C	Phyto-phagous	Cryptogenic	2003, GB	GB	I2	Unknown	Agassiz (2007)

Table 11.2. List and characteristics of the lepidopteran species expanding within Europe (alien *in* Europe). Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 01/06/2009.

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Arctiidae						
Eilema caniola (Hübner, 1808)	Phytophagous	Europe, W Asia & N Africa	AT, BE, CH	B3	Algae and lichens	Fologne (1859), Huemer and Rabitsch (2002), Kenis (2005)
Autostichidae						
Oegoconia novimundi Busck, 1915	Detrivorous	?, described from North America	AT, GR, HR, PT-AZO, SK, RU	G, F4-9, FA,G, J6	Decaying plant material	Gozmány (2008), Huemer and Rabitsch (2002), Karsholt and Vieira (2005), Tokár et al. (2002)
Coleophoridae						
Coleophora coracipennella (Hübner, 1796)	Phytophagous	W Europe	PT-MAD	I1, I2, X24	*Malus*	Aguiar and Karsholt (2006)
Coleophora laricella (Hübner, 1817)	Phytophagous	European Alps	BE, DK, HR, EE, FI, GB, HR, IE, LT, LV, MK, NL, NO, RS, SE	G3	*Larix*	Bond et al. (2006), De Fré (1858)
Coleophora spiraeella Rebel, 1916	Phytophagous	C Europe (incl. CZ, AU)	DE, HU, IT, LT, SE, SK	G, I2	*Spiraea*	Baldizzone (pers. comm.), Huemer and Rabitsch (2002), Reiprich and Janovský (1981)
Coleophora versurella Zeller, 1849	Phytophagous	Europe	PT-AZO	E1	*Atriplex, Chenopodium*	Karsholt and Vieira (2005)
Epermeniidae						
Epermenia aequidentellus (Hoffmann, 1867)	Phytophagous	C & S Europe	PT-AZO	U	*Daucus carota*	Karsholt and Vieira (2005)
Ethmiidae						
Ethmia terminella Fletcher, 1938	Phytophagous	Europe to N Africa and Asia Minor	SE	B2	*Echium vulgare*	Svensson (1992)

Family *Species*	Regime	Native range	Invaded countries	Alien Habitat	Hosts	Refs
Gelechiidae						
Athrips rancidella (Herrich-Schäffer, 1854)	Phyto-phagous	Europe	GB	I2	*Cotoneaster horizontalis*	Chalmers-Hunt (1985)
Chrysoesthia sexguttella (Thunberg, 1794)	Phyto-phagous	Europe and/or N Africa	PT-AZO	D6	*Chenopodium*	Karsholt and Vieira (2005)
Gelechia senticetella (Staudinger, 1859)	Phyto-phagous	European Alps	BE, DK, GB, NL, BU	I2, G	*Juniperus, Cupressus*	De Prins (1989), van Nieukerken et al. (1993), Buhl et al. (2007)
Platyedra subcinerea (Haworth, 1828)	Phyto-phagous	Europe	PT-AZO	I2	*Malva sylvestris*, seeds, flowers	Karsholt and Vieira (2005)
Geometridae						
Bupalus piniaria (Linnaeus, 1758)	Phyto-phagous	Europe	IE	G3	*Pinus*	Moffat (1897)
Erannis defoliaria (Clerck, 1759)	Phyto-phagous	Europe	IS	G1, I2	Polyphagous (*Quercus, Betula, Ulmus, Acer, Tilia)*	Wolff (1971)
Eupithecia carpophagata Staudinger, 1871	Phyto-phagous	Mediterranean	DE	E4	*Silene* (*S. saxifraga, S. rupestris*)	Geiter et al. (2001)
Eupithecia indigata (Hübner, 1813)	Phyto-phagous	Europe from Urals W and S to Alps	IE	G3	*Pinus sylvestris*, *Picea*, *Larix*	Skou (1986)
Eupithecia phoeniceata (Rambur, 1834)	Phyto-phagous	Atlantic Europe	BE, GB	I2	*Juniperus phoenicea*	De Prins (2007)
Eurranthis plummistaria (De Villers, 1789)	Phyto-phagous	Mediterranean	DE	F6	*Dorycnium*	Geiter et al. (2001)
Idaea inquinata (Scopoli, 1763)	Phyto-phagous	S Europe to Asia Minor, N Africa	DK, FI, LV, NL, SE	G1,G5,J1	Ever-lasting flowers/dry and withered petals	Naves (1995), Skou (1986), Wolff (1969)
Macaria liturata (Clerck, 1759)	Phyto-phagous	Europe to E Asia	IE	G3	*Pinus sylvestris*	Roques et al. (2006)

Family *Species*	Regime	Native range	Invaded countries	Alien Habitat	Hosts	Refs
Operophtera brumata (Linnaeus, 1758)	Phyto-phagous	Europe to Caucasus	IS	G	Deciduous trees	Peterson and Nilssen (2004)
Peribatodes perversaria (Boisduval, 1840)	Phyto-phagous	Europe	DE	F4	*Juniperus*	Savela (2010)
Thera britannica (Turner, 1925)	Phyto-phagous	Europe	SE	G3	*Abies*, *Pinus*	Skou (1986), Svensson (1977)
Gracillariidae						
Cameraria ohridella Deschka & Dimić, 1986	Phyto-phagous	Southern Balkans	AT, BA, BE, BG, BY, CH, CZ, DE, DK, ES, FI, FR, FR-COR, GB, HR, HU, IT, LV, LT, NL, PL, RO, RU, RS, SE, SI, SK, UK	I2, X11, FA, G1	*Aesculus hippocastanum*	Buhl et al. (2003), Butin and Führer (1994), De Prins and Puplesiene (2000), Hill et al. (2005), Huemer and Rabitsch (2002), Karsholt and Kristensen (2003), Łabanowski and Soika (1998), Laštůvka et al. (1994), Milevoj and Maček (1997), Šefrová and Laštůvka (2001), Stigter et al. (2000), Vives Moreno (2003)
Caloptilia rufipennella (Hübner, 1796)	Phyto-phagous	Europe	LT, LV, NO, SE	I2, G3	*Acer pseudoplatanus*	Kimber (2008)
Caloptilia roscipennella (Hübner, 1796)	Phyto-phagous	Europe or SW Asia?	AT, BE, CH, CZ, DE, ES, FR, FR-COR, HU, IT, IT-SIC, MD, PL, RO, RU, UK	I2, G3	*Juglans regia*	Šefrová and Laštůvka (2005)
Phyllonorycter geniculella (Ragonot, 1874)	Phyto-phagous	Europe	GB, LV, LT, SE	I2, G5	*Acer pseudoplatanus*	Emmet et al. (1985)
Phyllonorycter joannisi (Le Marchand, 1936)	Phyto-phagous	Europe	GB	I2, G5	*Acer platanoides*	Emmet et al. (1985)

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Phyllonorycter messaniella (Zeller, 1846)	Phyto-phagous	Europe	PT-AZO	I2, G	*Quercus, Fagus, Castanea*	Aguiar and Karsholt (2006), Karsholt and Vieira (2005)
Phyllonorycter strigulatella (Zeller, 1846)	Phyto-phagous	Europe	GB	G,J1, H1	*Alnus incana*	Hill et al. (2005)
Lasiocampidae						
Dendrolimus pini (Linnaeus, 1758)	Phyto-phagous	Most of Europe E to Urals and S to S. Italy and Sicily, NW North Africa and Asia Minor to Caucasus and Near East	GB	G3	*Pinus* spp.	Kimber (2008), Mikkola and Ståhls (2008)
Lyonetiidae						
Leucoptera malifoliella (O. Costa, 1836)	Phyto-phagous	Mediterranean	PT-MAD	I1, G1, G2	Polyphagous, mostly Rosaceae *(Malus, Pyrus, Sorbus, Crateagus, Prunus), Betula*	Aguiar and Karsholt (2006)
Nepticulidae						
Acalyptris platani (Müller-Rutz, 1934)	Phyto-phagous	E Balkans	CH, ES, HR, FR, FR-COR, IT, PT, SI,	FA, G, I2, X11	*Platanus*	van Nieukerken et al. (2004)
Ectoedemia heringella (Mariani, 1939)	Phyto-phagous	S. Europe (Adriatic)	GB	I2, G2	*Quercus ilex* leaf miner	Hill et al. (2005)
Stigmella atricapitella (Haworth, 1828)	Phyto-phagous	Europe	PT-MAD, ES	G1,G4,X10	*Quercus*	Aguiar and Karsholt (2006)
Stigmella aurella (Fabricius, 1775)	Phyto-phagous	Europe	PT-AZO	I1	*Rubus*	Karsholt and Vieira (2005)
Stigmella centifoliella (Zeller, 1848)	Phyto-phagous	Europe	PT-MAD	B1,X24,X25	*Rosa*	Aguiar and Karsholt (2006)

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Stigmella pyri (Glitz, 1865)	Phyto-phagous	Europe	SE	I1	*Pyrus*	Johansson et al. (1990)
Stigmella speciosa (Frey, 1857)	Phyto-phagous	Europe	DK, GB	G, I2	*Acer pseudoplatanus*	Heath and Emmet (1983)
Stigmella suberivora (Stainton, 1869)	Phyto-phagous	S Europe	GB	G3,G4	*Quercus ilex*	Heath and Emmet (1983)
Noctuidae						
Caradrina ingrata Staudinger, 1897	Phyto-phagous	E Mediterranean, N & NE Africa	CH	I2, X11		Rezbanyai-Reser (1983)
Chrysodeixis chalcites (Esper, 1789)	Phyto-phagous	Mediterranean &/or tropical Africa	CZ, PL, SE	J100, I1	Vegetables in glasshouses	Šefrová and Laštůvka (2005)
Euplexia lucipara (Linnaeus, 1758)	Phyto-phagous	Europe & W Asia, N Africa	PT-AZO	G	Ferns	Karsholt and Vieira (2005)
Lithophane leautieri (Boisduval, 1829)	Phyto-phagous	Mediterranean expanding to C Europe, N Africa	DK, GB, NL	I2	*Chamaecyparis, Cupressocyparis*	Bednova and Belov (1999), Bech (2009), Heath and Emmet (1983), (Vanholder (2000), Vuure (1981)
Polychrysia moneta (Fabricius, 1787)	Phyto-phagous	C & SE Europe to W Asia	BE, DK, DE, GB	I2	*Delphinium*	Kimber (2008)
Sesamia nonagrioides (Lefèbvre, 1827)	Phyto-phagous	S Europe, N, W, and SW Africa	PT-AZO, PT-MAD	I1	Corn, sugar cane	Aguiar and Karsholt (2006), Karsholt and Vieira (2005)
Spodoptera littoralis (Boisduval, 1833)	Phyto-phagous	Subtropical Africa Madagascar and S Europe	AL, CH, DE, DK, ES, ES-CAN, FR, FR-COR, GB, IT, IT-SIC, PT, PT-MAD	F5, F6, F8, I1, I2	Polyphagous (vegetables, flowers, fruit trees, introduced with *Chrysanthemum*)	Hoffmeyer (1962), Roll et al. (2007), Valletta (1949)
Nolidae						

Family *Species*	Regime	Native range	Invaded countries	Alien Habitat	Hosts	Refs
Earias vernana (Fabricius, 1787)	Phyto-phagous	C&S Europe & W Asia	SE	G,FA	*Populus alba*	Hyden et al. (2006)
Notodontidae						
Thaumetopoea pityocampa (Denis & Schiff., 1775)	Phyto-phagous	S Europe & N Africa	IT-SAR	G3	*Pinus* spp	Mendes (1905)
Nymphalidae						
Pararge aegeria (Linnaeus, 1758)	Phyto-phagous	Europe to E Asia and N Africa	PT-MAD	G2,X10	*Brachypodium sylvaticum* (Poaceae)	Aguiar and Karsholt (2006), Jones and Lace (1992)
Oecophoridae						
Endrosis sarcitrella (Linnaeus, 1758)	Detri-vorous	Mediterranean?	AT, BE, BY, CH, CZ, DE, DK, EE, FI, GB, IE, IS, LT, LV, NL, NO, PL, RO, SE, SK	J1, G	Carpets, corks of wine bottles, dried plant material, dried foodstuffs indoors. Occurs outdoors in dried bracket-fungi on trees	Abafi-Aigner et al. (1896), Hrubý (1964), Martin (1991), Mehl (1977), Šefrová and Laštůvka (2005), Ulmer et al. (1918)
Hofmannophila pseudospretella (Stainton, 1849)	Detri-vorous	Mediterranean?	AT, BE, BY, CH, CZ, DE, DK, EE, FI, GB, IS, IE, LT, LV, NL, NO, PL, PT, RO, SE, SK	J1, I2	Fabrics, including carpets, upholstery, leather and books, but more especially infesting dried foodstuffs	Amsel (1959), Hill et al. (2005), Hrubý (1964), Jürivete et al. (2000), Mehl (1977), Šefrová and Laštůvka (2005)
Pieridae						
Pieris rapae (Linnaeus, 1758)	Phyto-phagous	Palaeartic and N America, Australia	PT-MAD	X22, X23, X24, X25	*Brassica*	Aguiar and Karsholt (2006)
Plutellidae						

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Plutella porrectella (Linnaeus, 1758)	Phyto-phagous	Europe and Asia Minor, expanding throughout N America	SE	E5, I2	*Hesperis matronalis*	Gustaffson (2010)
Pterophoridae						
Emmelina monodactyla (Linnaeus, 1758)	Phyto-phagous	Europe, Africa, Asia, and/or N America, Mexico	PT-AZO	E, F, I2	Bindweeds (*Convolvulus* and *Calystegia spp*.), occasionally Morning glory (*Ipomoea*), *Chenopodium* and *Atriplex*	Karsholt and Vieira (2005)
Stenoptilia millieridactylus (Bruand, 1861)	Phyto-phagous	Atlantic Europe	GB, IE	I2	Wild Mossy saxifrage (*Saxifraga hypnoides*)	Hill et al. (2005)
Pyralidae + Crambidae						
Aglossa caprealis (Hübner, 1809)	Detri-vorous	Mediterranean	AT, BE, CZ, DE, DK, GB, NL, PL, PT-AZO, PT-MAD	J1	Stored Products	Aguiar and Karsholt (2006), Buhl et al. (2007), Karsholt and Vieira (2005), Šefrová and Laštůvka (2005)
Apomyelois ceratoniae (Zeller, 1839)	Detri-vorous	Medi-terrranean?	AT, BE, CH, CZ, DE, DK, GB, HU, NL, NO, PL, RO, RU, SE, UK	J1	Stored products: dry fruits, dates, nuts, carob, pistachio	Palm (1986), Sterneck and Zimmermann (1933)
Cadra calidella (Guenée, 1845)	Detri-vorous	Mediterranean	AT, BE, CH, CZ, DE, DK, FI, GB, IE, NL, NO, RO, SE, SK	J1	Dried fruits, nuts, figs	Hance (1991), Huemer and Rabitsch (2002), Mehl (1979), Palm (1986), Reiprich (1989), Vlach (1938)

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Duponchelia fovealis Zeller, 1847	Phyto-phagous	Mediterranean and Canary Islands	BE, CZ, DE, DK, FI, GB, NL, NO, SE	J100, J1	Polyphagous in greenhouses (*Begonia, Gerbera, Cyclamen, Anthurium, Kalanchoe, Poinsettia, Rosa,* aquatic plants, maize, pepper and other vegetables), can reproduce outside, but surviving winters	Buhl et al. (2006), Deurs (1958), Huisman and Koster (1995), Marek and Bártová (1998)
Euclasta varii (Popescu-Gorj & Constantinescu, 1973)	Phyto-phagous	SW Europe (Spain)	MT	F6	Palm trees (*Phoenix canariensis* and *P. dactilifera*)	Sammut (2005)
Sclerocona acutellus (Eversmann, 1842)	Phyto-phagous	S & C Europe to Asia (apparently expanding to Siberia, China and E USA)	GB	B, E	Grass stems used for thatching	Wagner et al. (2003)
Saturniidae						
Graellsia isabellae Graells, 1849	Phyto-phagous	SW Europe (Spain, France)	CH	G3	*Pinus sylvestris*	Lepidopterologen Arbeitsgruppe (2000)
Sesiidae						
Pennisetia hylaeformis (Laspeyres, 1801)	Phyto-phagous	Europe to W Asia	GB	I1, I2	*Ribes*	Reiprich (1980)
Synanthedon andrenaeformis (Laspeyres, 1801)	Phyto-phagous	Europe &/or Asia Minor to W Asia	SE	I2	*Viburnum lantana*	Torstenius and Lindmark (2000)
Synanthedon myopaeformis (Borkhausen, 1789)	Phyto-phagous	SC Europe &/ or Asia Minor and Egypt	PT-MAD	I2	*Malus*	Aguiar and Karsholt (2006)

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Tineidae						
Haplotinea ditella (Pierce & Metcalfe, 1938)	Detri-vorous	Mediterranean	AT, BE, CZ, DE, DK, FI, GB, LT, NL, NO, PL, RU, SE, SK	J1	Cereals	Heath and Emmet (1985), Ivinskis (1988), Reiprich (1991), Šefrová and Laštůvka (2005)
Haplotinea insectella (Fabricius, 1794)	Detri-vorous	Mediterranean	AT, BE, CH, CZ, DE, DK, FI, GB, IE, LT, NL, NO, PL, RU, SE, SK	J1	Stored products	Heath and Emmet (1985), Hrubý (1964), Ivinskis and Mozūraitis (1995), Mehl (1977), Šefrová and Laštůvka (2005)
Tinea murariella Staudinger, 1859	Detri-vorous	Mediterranean?	CH, ES, FR, GB, HR, IT, IT-SIC, NO, PT, PT-AZO, PT-MAD, RO	J1	Stored products	Adams (1979), Gaedike and Karsholt (2001), Karsholt and Vieira (2005), Opheim and Fjeldså (1983)
Trichophaga tapetzella (Linnaeus, 1758)	Detri-vorous	Mediterranean?	AL, AT, BE, BG, BY, CH, CY, CZ, DE, DK, EE, FI, FR, FR-COR, GB, GR-CRE, HR, IE, IT-SAR, LU, LV, LT, NL, NO, PL, PT-AZO, SE, SI, SK, UK	J1	Stored products	De Graaf (1851), Hrubý (1964), Karsholt and Vieira (2005), Lederer (1863), Palionis (1932), Robinson and Nielsen (1989), Šefrová and Laštůvka (2005)
Tortricidae						
Acleris variegana (Denis & Schiffermüller, 1775)	Phyto-phagous	Europe	PT-AZO	FB	*Rosa*	Karsholt and Vieira (2005)
Adoxophyes orana (Fischer von Röslerstamm, 1834)	Phyto-phagous	Europe	GB	I1, I2	Polyphagous, fruit trees (*Prunus, Malus, Rosa*) and deciduous (*Alnus, Betula, Populus, Salix*)	Bradley et al. (1973)

Family *Species*	Regime	Native range	Invaded countries	Alien Habitat	Hosts	Refs
Cacoecimorpha pronubana (Hübner, 1799)	Phyto-phagous	S Europe	BE, CH, CZ, DE, DK, GB, HU, IE, LT, LU, NL	FB, I2, X11, G1, J100	Polyphagous, especially on *Dianthus* but also on *Acacia, Acer, Chrysanthemum, Citrus, Coriaria, Coronilla, Euphorbia, Ilex, Jasminum, Laurus, Mahonia, Malus, Olea, Pelargonium, Populus, Prunus, Rhododendron, Rosa, Rubus, Syringa*	Billen (1999), de Carvalho (1995), Glavendekić et al. (2005), Ivinskis (2004), Janmoulle (1974), Thygesen (1963)
Clavigesta sylvestrana (Curtis, 1850)	Phyto-phagous	Europe	PT-AZO, PT-MAD	*G3*	*Pinus*	Aguiar and Karsholt (2006), Karsholt and Vieira (2005)
Cydia grunertiana (Ratzeburg, 1868)	Phyto-phagous	E Europe	BE, DK, SE	I2	*Larix*	Falck and Karsholt (1993), Groenen and De Prins (2004)
Cydia illutana (Herrich-Schäffer, 1851)	Phyto-phagous	Europe	GB	G3	*Larix, Picea*	Hill et al. (2005)
Cydia milleniana Adamczewski, 1967	Phyto-phagous	Europe and Asia	BE, DK, GB	G3	*Larix*	Hill et al. (2005), Buhl et al. (2004)
Cydia pactolana (Zeller, 1840)	Phyto-phagous	Europe	GB	G3	*Picea*	Hill et al. (2005)
Cydia pomonella (Linnaeus, 1758)	Phyto-phagous	Europe, expanding to E USA	PT-AZO, PT-MAD	I1	*Malus*	Aguiar and Karsholt (2006), Karsholt and Vieira (2005)
Cydia splendana (Hübner, 1799)	Phyto-phagous	Europe	PT-AZO, PT-MAD	G1	*Castanea*, *Quercus* but also *Fagus* and *Juglans*, fruit borer	Aguiar and Karsholt (2006), Karsholt and Vieira (2005)
Cydia strobilella (Linnaeus, 1758)	Phyto-phagous	Europe	NL		*Picea*, cone borer	Coldewey and Vári (1947)
Notocelia rosaecolana (Doubleday, 1850)	Phyto-phagous	Europe	IS	I2	*Rosa*	

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Alien Habitat**	**Hosts**	**Refs**
Rhopobota naevana (Hübner, 1817)	Phyto-phagous	Europe	PT-AZO	I2	Holly (*Ilex aquifolium*) and blueberry (*Vaccinium myrtillus*)	Karsholt and Vieira (2005)
Rhyacionia buoliana (Denis & Schiffermüller, 1775)	Phyto-phagous	Europe expanding to N America	PT-MAD	X15,X16	*Pinus*	Aguiar and Karsholt (2006)
Selania leplastriana (Curtis, 1831)	Phyto-phagous	Mediterranean and/or N Africa, Asia Minor	SE	I1	*Brassica*	Svensson (2006)
Yponomeutidae						
Argyresthia laevigatella (Heydenreich, 1851)	Phyto-phagous	N or C Europe &/or Japan	DK, FI, GB, HU, IE, LT, LV, NL, NO, SE	G3	*Larix* shoots	Kimber (2008)
Argyresthia trifasciata Staudinger, 1871	Phyto-phagous	European Alps	AT, BE, CZ, DE, DK, GB, HU, LV, NL, PL, SE, SI, SK	I2, FA	*Juniperus* (not spiked species), very occasionally *Cupressocyparis, Chamaecyparis*	Buhl et al. (1998), De Prins (1996), Gomboc (2003), Huemer and Rabitsch (2002), Šefrová and Laštůvka (2005)
Prays oleae (Bernard, 1788)	Phyto-phagous	Mediterranean	PT-AZO	I2, J100	*Olea* (240) trees	Karsholt and Vieira (2005)
Zelleria oleastrella (Millière, 1864)	Phyto-phagous	Mediterranean	GB, PT-MAD	I2, J100	*Olea* (240) trees	Aguiar and Karsholt (2006)
Zygaenidae						
Theresimima ampellophaga (Bayle-Barelle, 1808)	Phyto-phagous	Mediterranean	AT	I1	*Vitis vinifera*	Huemer and Rabitsch (2002), Prinz (1907), Tarmann (1998)

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Hymenoptera
Chapter 12

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Abstract

We present the first review of Hymenoptera alien *to* Europe. Our study revealed that nearly 300 species of Hymenoptera belonging to 30 families have been introduced to Europe. In terms of alien species diversity within invertebrate orders, this result ranks Hymenoptera third following Coleoptera and Hemiptera. Two third of alien Hymenoptera are parasitoids or hyperparasitoids that were mostly introduced for biological control purposes. Only 35 phytophagous species, 47 predator species and 3 species of pollinators have been introduced. Six families of wasps (Aphelinidae, Encyrtidae, Eulophidae, Braconidae, Torymidae, Pteromalidae) represent together with ants (Formicidae) about 80% of the alien Hymenoptera introduced to Europe. The three most diverse families are Aphelinidae (60 species representing 32% of the Aphelinid European fauna), Encyrtidae (55) and Formicidae (42) while the Chalcidoidea together represents 2/3 of the total Hymenoptera species introduced to Europe. The first two families are associated with mealybugs, a group that also included numerous aliens to Europe. In addition, they are numerous cases of Hymenoptera introduced from one part of Europe to another, especially from continental Europe to British Islands. These introductions mostly concerned phytophagous or gall-maker species (76 %), less frequently parasitoids. The number of new records of alien Hymenoptera per year has shown an exponential increase during the last 200 years. The number of alien species introduced by year reached a maximum of 5 species per year between 1975 and 2000. North America provided the greatest part of the hymenopteran species alien *to* Europe (96 species, 35.3%), followed by Asia (84 species, 30.9%) and Africa (49 species, 18%). Three Mediterranean countries (only continental parts) hosted the largest number of alien Hymenoptera: Italy (144 spp.), France (111 spp.) and Spain (90 spp.) but no correlation was found with the area of countries. Intentional introduction, mostly for biological control, has been the main pathway of introduction for Hymenoptera. Consequently, the most invaded habitats are agricultural and horticultural as well as greenhouses. To the contrary, Hymenoptera alien *in* Europe are mostly associated with woodland and forest habitats. Ecological and economic impacts of alien Hymenoptera have been poorly studied. Ants have probably displaced native species and this is also true for introduced parasitoids that are suspected to displace native parasitoids by competition, but reliable examples are still scarce. The cost of these impacts has never been estimated.

Keywords

Hymenoptera, alien, Europe, biological invasions

12.1. Introduction

Hymenoptera is one of the four large insect orders exceeding 100 000 species in the world, the other major orders being Coleoptera, Lepidoptera and Diptera (Gauld and Bolton 1988, Goulet and Huber 1993). The Hymenoptera order contains about 115 000 described species and authors estimated that there are between 300,000 and 3,000,000 species of Hymenoptera (Gaston 1991), possibly around 1,000,000 (Sharkey 2007). These estimates mean that only 1/10 has been described so far and 9/10 awaits description. However, the number of Hymenoptera species is difficult to estimate with accuracy, as most of the mega diverse regions of the world have not been extensively studied and inventoried regarding this group (LaSalle and Gauld 1993). In Europe, about 15,000 species have been reported belonging to 73 families, but undoubtedly thousands of species remains to be discovered and described. From our recent review of the literature, the alien species of Hymenoptera comprise 286 species belonging to 30 families. The order ranks third just following the Coleoptera and the Hemiptera in terms of alien species diversity (Roques et al. 2008). Additionally, 71 European species have been translocated from one part of Europe to another (adding 5 more families) and 11 species are considered cryptogenetic. All together within Europe, at least 368 Hymenoptera species have been introduced in different parts of the continent.

Hymenoptera have been traditionally subdivided into three assemblages (the paraphyletic sub-order Symphyta and the monophyletic Aculeata and Parasitica belonging to the sub-order Apocrita). Each group exhibits different biology. 'Symphyta' are mostly phytophagous and are the most primitive members of the order. Parasitica are mainly parasitic species but some of them have returned secondarily to phytophagy, while Aculeata encompass a larger spectrum (predators, pollinators, parasitoids); all eusocial hymenoptera belong to this last group.

Members of the Hymenoptera are familiar to a general audience and common names exist for a large variety of groups: "wasps", "bees", "ants", "bumblebees", "sawflies", "parasitic wasps". Hymenoptera adult sizes range from the very small Mymaridae (0.5 mm) to the large aculeate wasps (up to 5 cm long in Europe). This group of mandibulate insects is well defined by the combination of several characters: they have two pairs of functional wings (with the exception of apterous species) bearing fewer veins than most other insect groups and rarely more than seven cross veins. The abdominal tergum 1 is fused to the metanotum and in most Hymenoptera the metasoma (apparent gaster) is joined to the mesosoma (apparent thorax) by a petiole.

Hymenoptera have two main larval types. 'Symphyta' have larvae that are caterpillar-like, but true caterpillars (Lepidoptera) have at most four pairs of prolegs (abdominal segments 3–6) while sawflies larvae have at least five pairs of prolegs (abdominal segments 2–6). Furthermore the prolegs of Symphyta do not bear crochets, whereas those of Lepidoptera larvae do. 'Apocrita' have legless grub-like larvae that are nearly featureless unless they have a differentiated head (Goulet and Huber 1993). All Hymenoptera have haplodiploid sex determination (haploid males and diploid females). Arrhenotoky is the most common mode of reproduction in Hymenoptera (Heimpel and de Boer 2008). The males develop parthenogenetically from unfertilised eggs while the females develop from fertilised eggs. Females can control fertilisation by releasing sperm to an egg upon oviposition, and can thus adjust the sex-ratio of their progeny.

Ecologically and economically few groups of insects are as important to mankind as the Hymenoptera. Bees provide the vital ecosystem service of pollination in both natural and managed systems (Gallai et al. 2009) while parasitic Hymenoptera control populations of phytophagous insects (Tscharntke et al. 2007) and can be effective agents for control of pest insects (Bale et al. 2008, Brodeur and Boivin 2004, Jonsson et al. 2008). Some of the phytophagous hymenoptera have an intimate association with their host-plants (Nyman et al. 2006) and can also be considered as major pests to forests (e.g. Diprionidae) (De Somviele et al. 2004, Lyytikainen-Saarenmaa and Tomppo 2002). Ant invasions cause huge economic and ecological costs (Holway 2002, Lach and Thomas2008) and Hymenoptera stings, specifically those of wasps, hornets and bees cause serious allergic reactions and anaphylaxis (Flabbee et al. 2008, Klotz et al. 2009).

12.2. Taxonomy of alien species

The 286 species of Hymenoptera alien *to* Europe belong to 30 different families (Table 12.1), which also have native representatives. Among these alien species, 35 species are phytophagous, 1 detritivorous, 3 pollinators, 47 predators whilst 200 are parasitoids or hyperparasitoids. These results show that only 13.3% of the alien wasp and bee species are phytophagous (including pollinators), the great majority of which (86.4 %) are predators and parasitoids (respectively 16.4% and 70.0%). Most parasitoids were intentionally introduced to control pests. Interestingly, among the 71 Hymenoptera that have been introduced from one part of Europe to another (aliens *in* Europe - Table 12.2), an opposite proportion is observed. Fifty-four species (76.0 %) are phytophagous and only 17 (23.9%) are parasitic or predatory. These species have mostly followed their host plants throughout Europe.

Consequently, most alien Hymenoptera in Europe belong to the sub-order Parasitica (228 spp. and 20 families, 79.4% of the species), while Aculeata (51 spp. and 7 families, 17.8%) and Symphyta (8 spp. and 3 families, 2.8%) are less represented. Six families of wasps (Aphelinidae, Encyrtidae, Eulophidae, Braconidae, Torymidae, Pteromalidae) represent together with ants (Formicidae) about 80% of the alien Hymenoptera in Europe. Each of these families has more than 10 introduced species in Europe. The three most diverse families in terms of alien species are Aphelinidae (60 species), Encyrtidae (55) and Formicidae (42). By far the richest superfamily is the Chalcidoidea that includes 198 alien species (69.2% of the total alien Hymenoptera). Below we give a short synopsis for all Hymenoptera families containing introduced species to Europe (including cryptogenic and translocated species).

Suborder Symphyta

Argidae. The second largest family of 'Symphyta' with about 1000 species described, but only 60 in Europe. Alien species *to* Europe have not yet been found. One species only, *Arge berberidis,* is considered as introduced from one part of Europe to another,. Females deposit eggs in leafs of various angiosperms and the larvae are phytophagous, feeding mostly on woody plants (Salicaceae, Rosaceae, Betulaceae).

Blasticotomidae. This is a very small family represented by one species only, *Blasticotoma filiceti*, in northern and central Europe. Larvae are stem borers, developing within the rachis of ferns (e.g., *Athyrium filix-femina* (L.) Roth) (Schedl 1974). *B. filiceti* has been infrequently introduced into Great Britain from continental Europe, mostly with horticultural plants.

Diprionidae. A small family of 'Symphyta' that mostly occurs in northern Europe. It comprises about 100 species in the northern hemisphere, of which 20 occur in Europe. The larvae attack softwood trees (e.g. conifers) and are considered as major pests in forestry. Diprioninae develop on Pinaceae and Monocteninae on Cupressaceae, but only the first subfamily contains invaders. Alien species have not yet been recorded. However, five species are considered as alien *in* Europe. *Neodiprion sertifer* and *Gilpinia hercyniae* cause severe damage to pine and spruce plantations. Females of some species produce pheromones that attract males. The larvae consume needles, sometimes gregariously, and when mature drop to the ground, pupate and overwinter within a cocoon (rarely upon trees). Diapause can last for more than one winter (Pschorn Walcher 1991), the wasps emerging and dispersing in the early spring.

Pamphiliidae. A small holarctic family containing about 60 species in Europe (van Achterberg and van Aartsen 1986, Viitasaari 2002). Only *Cephalcia alashanica* is an alien species introduced from temperate Asia. Six other species are alien in Europe, most of them having been introduced from the Alps to northern countries with their host trees. Some species attack conifers and are considered as forest pests. Females lay eggs in a slit cut in a needle, the normally gregarious larvae either spin silk webs in which they develop (Cephalciinae) or roll the host plant leaves (Pamphiliinae). They overwinter as pupae within pupal chambers in the soil and adults emerge in early spring.

Siricidae. A small Holarctic family (16 European species) of large and conspicuous wasps (woodwasps). Nine species are considered as alien in Europe, with only 5 alien species introduced from North America with imported timbers. The family is subdivided into two subfamilies, the Siricinae attacking conifers and the Tremecinae that attack angiosperm trees. The females, which do not feed, oviposit in recently fallen or dying trees and introduce spores of symbiotic fungus along with the eggs. The larvae develop in 2 or 4 years as woodborers and pupate in the bark.

Tenthredinidae. This cosmopolitan family is the most diverse group of 'Symphyta' including 1050 species in Europe of which only two are alien *to* Europe , *Nematus* (*Pteronidea*) *tibialis* (a pest of black locust) and *Pachynematus* (*Larinematus*) *itoi* (a larch pest) and 23 alien *in* Europe. Some native European species are also considered serious pests in North America where they have been introduced. All species are phytophagous and the larvae are mostly external feeders on diverse species of angiosperms and conifers. The females embed their eggs in the tissue of the plant, using their ovipositor as a saw. The larvae feed singly on leaves, or are stem borers, gall makers or leaf miners. Tenthredinidae mostly overwinter as prepupae in the ground, sometimes as mature larvae or eggs, the adults emerge relatively early in the spring.

Suborder Apocrita Parasitica

Chalcidoidea

Agaonidae. A small-sized family with only 6 species of wasps reported in Europe, four of which are introduced from tropical Asia, along with two ornamental trees *Ficus microcarpa* L.f. and *F. religiosa* L. Agaonidae are the pollinators of fig trees and are mutualistically associated with their host plant. Several groups of non-pollinating fig wasps are associated with figs, either as gall-makers, inquilines or parasitoids. Their taxonomic position has been discussed and they are here grouped within Agaonidae for convenience (Bouček 1988, Rasplus et al. 1998).

Aphelinidae. This is a moderately sized family of wasps represented in Europe by less than 200 species of which sixty are aliens. Aphelinidae species have been introduced from diverse geographic areas as biological control agents. Along with encyrtid, the Aphelinidae is the most important family for biological control. Species are primarily endoparasitoids or ectoparasitoids, sometimes hyperparasitoids, of sternorrhynchous Hemiptera (mostly Aphidoidea, Coccoidea or Aleyrodoidea). Some species may have complicated ontogeny (Hunter and Woolley 2001) and males and females may attack different hosts either as parasitoids or hyperparasitoids.

Chalcididae. A small family of chalcid wasps comprising about 80 species in Europe, including one alien species, introduced from North Africa to control fruit flies.

The hosts of these obligate parasitoids or hyperparasitoids are mostly Lepidoptera and Diptera, less frequently Coleoptera, Neuroptera or Hymenoptera (Delvare 1995, Delvare 2006). The females lay eggs within the host larva and the pupation take place in the host pupa.

Encyrtidae. A large family of wasps represented by more than 700 species in Europe (Trjapitzin 1989), of which 55 are considered to be alien, introduced from different parts of the world for biological control of economically important pests (Noyes and Hayat 1994). Most of the Encyrtidae are endoparasitoids of scale insects. Some species also develop as endoparasitoids of other insect orders, mostly Lepidoptera, Coleoptera and Hymenoptera). The egg is laid inside the host and the larva develop as a parasitoid sometimes as an hyperparasitoid, and pupates within the host.

Eulophidae. A large family of wasps that contains 1100 species in Europe (Gauld and Bolton 1988), including 29 alien species. Most alien species have been introduced for biological control but a few (3) are gall makers that develop at the expense of plant tissue of *Eucalyptus* (Branco et al. 2009). Eulophid are primarily solitary parasitoids of eggs, pupae or larvae of various endophagous insects (Diptera, Coleoptera, Thysanoptera, Lepidoptera or Hymenoptera). Some species attack economically important leaf miners or gall makers (e.g. Agromyzidae, Cecidomyiidae).

Eupelmidae. A small family represented by about 100 native (Gibson 1995) and 5 alien species in Europe (*Eupelmus* and *Anastatus* spp.). Eupelmidae are primarily ectoparasitoids (idiobionts) of egg or larval stages of various insects and spiders (Askew et al. 2000). Some species within this family are generalist parasitoids.

Eurytomidae. A medium-sized family with about 300 species in Europe (Zerova 1978), of which seven are alien. Interestingly, these alien species are not parasitoids but phytophagous and pests of crops or horticultural plants whilst most eurytomids are primarily ectoparasitoids or hyperparasitoids of extremely diverse groups of endophagous insects (Lotfalizadeh et al. 2007). Phytophagous species are either stem-borers or seed-feeders or gall-makers on different host-plant groups (e.g. Graminaceae, Leguminosae). Some species are both entomophagous then phytophagous during their larval development.

Mymaridae. A medium-sized family including about 450 species in Europe, of which only two are alien, *Anaphes nitens* and *Polynema striaticorne*. All mymarids are internal, solitary (rarely gregarious) parasitoids of the eggs of various insects (Huber 1986). The most common hosts are eggs of Hemiptera Auchenorrhyncha (Cicallidae, Cixiidae) but mymarids also parasitize eggs of other insects (Coleoptera, Hemiptera). Female oviposit within concealed eggs, and there are 2 to 4 larval stages.

Perilampidae. A small family of chalcid wasps that includes 40 European species. The only alien species in this family (*Steffanolampus*) originates from North America and is a parasitoid of wood-boring Coleoptera. Most perilampids are hyperparasitoids of Lepidoptera through Tachinidae (Diptera) or Ichneumonoidea (Steffan 1952). Females deposit their eggs away from the host, however the young larvae (planidium) are mobile, and may either attach themselves to the primary host, at any stage of larval development, or enter the host to attach to its endoparasitoids. In some species, an adult host carries the larva to a suitable location where host larvae occur (Darling 1999).

Pteromalidae. A large, paraphyletic family including more than 1100 species in Europe (Graham 1969). Only ten are considered alien species, most of which were unintentionally introduced with their hosts, some (3) for biological control purposes. The diversity of the group is reflected by the diversity of the biology exhibited. Pteromalids are mostly ectoparasitoid *idiobionts*, but some species are *koinobionts*. Miscogasterinae are larvo-pupal endoparasitoids of dipteran leaf miners. Eunotinae (e.g. *Moranila*) are predators on Coccoidea eggs within the female body (Boucek and Rasplus 1991).

Signiphoridae. A small family of tiny chalcids (0.5–2 mm) comprising only 8 European species, one of which is an introduced hyperparasitoid (*Chartocerus*) (Woolley 1988). Signiphoridae are known as parasitoids (sometimes hyperparasitoids) of cyclorrhaphous dipterans, scale-insects (Coccoidea) or white-flies (Aleyrodidae).

Torymidae. A medium-sized family that includes about 350 European species (Grissell 1995, Grissell 1999), of which 13 are considered as alien *to* Europe. Most of the alien species (12) belong to the genus *Megastigmus* and are considered pest of conifer seeds (Roques and Skrzypczynska 2003). Most torymines are idiobiont ectoparasitoids of gall-makers (Cynipidae and Cecidomyiidae) and other endophytic insects but most Megastigminae are specialist phytophages. *Megastigmus* females lay their eggs in the ovules of conifers before fertilization has taken place (Roques and Skrzypczynska 2003) (Figure 12.9). *Megastigmus* biological habits have been shown to be particularly prone to invasion. Since most of their development takes place within seed, their presence is usually overlooked in traded seed lots, the infested seeds showing up only when X-rayed (Figure 12.10). In addition, insect are able to become dormant during the larval stage, for up to 5 years (prolonged diapause) following the annual size variations of the seed crop, thus broadening the chances that adult emergence will occur under favourable circumstances near a suitable new host. Moreover, some species such as the Douglas-fir seed chalcid, *M. spermotrophus,* appear capable of preventing the abortion of unfertilized seeds. The invasive insect larva may thus achieve its development in unpollinated, unfertilized seeds by altering the physiology of the ovule so that it allocates *de novo* resources to the larva (von Aderkas et al. 2005).

Trichogrammatidae. A moderately-sized family containing about 150 European species. The nine alien species belong mostly to three genera: *Trichogramma*, *Oligosota*, *Uscana* and have been introduced to Europe for the control of agricultural pests (Lepidoptera and Coleoptera) (Pintureau 2008). Trichogrammatids are primarily solitary or gregarious endoparasitoids of insect eggs (mostly Lepidoptera, Hemiptera, Coleoptera) and can sometimes develop as hyperparasitoids.

Ichneumonoidea

Ichneumonidae. This is the first megadiverse Apocrita family in Europe with about 5500 species, six of them are considered as alien *to* Europe. These species have been intentionally introduced for biological control. The family is divided into more than 30 subfamilies. Consequently, the biology of ichneumonids is extremely diverse. Ichneumonids mostly parasitize the immature stages of the Holometabola, and are frequently associated with Lepidoptera and sawflies (Hymenoptera). Ectoparasitism is considered the primitive condition and endoparasitism has evolved several times independently within the family.

Braconidae. Braconids represent the second megadiverse family with nearly 3500 European species, 16 of which are considered as alien. Altogether, Ichneumonoidea may account for nearly 10000 species in Europe. Like ichneumonids, braconids exhibit a large range of biological characteristics. They are mostly parasitoids of other insects. Some of the braconid groups are larvo-nymphal *koinobiont* parasitoids; others are *idiobiont* ectoparasitoids. Introduced species are mostly *koinobiont* endoparasitoids and are associated with aphids (Aphidiinae), moths (Miscogasterinae), and fruit flies (Opiinae).

Ceraphronoidea

Ceraphronidae. A small family represented by 100 European species, only one of which is considered as alien, *Aphanogmus bicolor*. Their biology is poorly known but some species are endoparasitoids of nematocerous dipterans whilst others attack Thysanoptera or Neuroptera. Some species are considered as antagonists of biological control agents since they are parasitoids of predaceous midges or hymenopteran primary parasitoids.

Cynipoidea

Cynipidae. A medium-sized family confined to the Holarctic and containing 350 European species. Only the chesnut gall wasp, *Dryocosmus kuriphilus*, is alien *to* Europe (Figure 10.8). Six more species, mostly from the genus *Andricus*, are considered as aliens *in* Europe. Most Cynipinae are gall inducers on *Quercus*, *Rosa* and some Compositae but others (Synergini) are inquilines.

Figitidae. This medium-sized family contains ca. 400 species in Europe, the family as presently understood includes the previous Eucoilidae, Charipidae and Anacharitidae (Ronquist 1995). Only one species (*Aganaspis daci*) is considered as alien and has been introduced to Europe for the control of fruitflies. Figitid larvae develop as internal parasitoids of other endophytic insect larvae. The hosts are mostly dipteran larvae but Charipinae Alloxystini are hyperparasitoids of aphids through Braconidae Aphidiinae and Aphelinidae. The egg is deposited inside a young host larva, which continues to develop normally (koinobionts), the parasitoid larvae emerges before the host death and can achieve its development as an ectoparasitoid.

Platygastroidea

Platygastridae. A medium-sized family with about 500 species in Europe but only two (*Amitus* spp.) are considered as alien, having been introduced into Europe for the control of whiteflies. Many Platygastridae are endoparasitoids of gall-making dipterans whilst others attack immature hemipterans or ant larvae. The biology of most species remains largely unknown. Some species are *thelytokous* and very few polyembryonnic. The larvae have an uncommon appearance and superficially resemble cyclopoid copepods.

Scelionidae. A medium-sized family that includes about 600 species in Europe, three of them considered as alien. Scelionids are primarily endoparasitoids in a wide variety of insect eggs (few on other arthropods), more rarely hyperparasitoids. Introduced species attack Hemiptera or Lepidoptera eggs and have been used for pest control. The family has been synonymized with Platygastridae but we still keep it apart for consistency (Murphy et al. 2007).

Suborder Apocrita Aculeata

Chrysidoidea

Bethylidae. A medium-sized family represented by about 230 species in Europe. Four species are considered alien. *Cephalonomia waterstoni*, *Holepyris sylvanidis* and *Plastanoxus laevis* are cosmopolitan. They were introduced into Europe with stored products. *Laelius utilis* is a parasitoid of *Anthrenus*. Bethylidae mainly attack larvae of Lepidoptera and Coleoptera. The female stings and paralyses the host, and then lays several eggs on its skin. Larvae develop as ectoparasitoids. For a few species, females tend the eggs and developing larvae. Pupation occurs next to the host remains.

Chrysididae. A medium- sized family that comprises 420 European species. Cukoo- wasps are parasitoids or kleptoparasitoids of Aculeate wasps. The nests of the host are sought out by the female chrysid that oviposits into the host cells. A true parasitoid larva develops as an ectoparasitoid on the host larva whilst a kleptoparasite larva kills the egg or the young larva of the host before consuming the stored food. One East European species introduced in western parts of Europe, *Chrysis marginata*, is considered as alien *in* Europe (Pagliano et al. 2000).

Dryinidae. A medium-sized family that comprises about 100 species in Europe. All dryinids are parasitoids of immature and adult Hemiptera Auchenorrhyncha. The larva is rather endoparasitoid than ectoparasitoid during the last instars, forming a bag (*thylacium*) constituted by the exuviae of the parasitoid and bulging from the host abdomen. Only one species alien *to* Europe, *Neodryinus typhlocybae*, was introduced in northern Italy and subsequently in France for biological control of the Nearctic planthopper *Metcalfa pruinosa* (Hemiptera, Flatidae) (Malausa et al. 2003, Malausa et al. 2008).

Apoidea

Apoidea represents a superfamily including more than 2000 species in Europe. Depending on the classification used, the group comprises seven families (ancient subfamilies of the single family Apidae) to eleven families if sphecid wasps, the sister group of bees, are included (Sharkey 2007). Here we followed the more recent classification system and adopted a subdivision into several families. Bees are flower visitors and efficient pollinators of angiosperms. Their larvae are phytophagous and develop on a mixture of pollen and nectars. Bees are now recognized as an important group of ecosystem engineers that modulate resources availability (i.e. plants) to other organisms (Jones et al. 1994). Two families of bees contain alien species in Europe. Sphecid wasps comprise 4 families of wasps that feed their progeny with a wide range of preys (mainly insects or spiders), depending on genera. All alien species belong to the family Sphecidae.

Apidae. This small family of *eusocial* bees includes social species, with colonies attaining large sizes. It comprises less than 70 species in Europe, all except one (*Apis meliffera*) belonging to the genus *Bombus*. Some of these pollinator species have been introduced from some parts of Europe into other European regions for crop pollination purposes and honey production.

Megachilidae. This family comprises about 480 species in Europe, two are considered as alien. The alfalfa leafcutter bee, *Megachile rotundata*, is a west European species that has been used commercially for pollination of alfalfa, and introduced in Russia. *Osmia cornifrons* is an alien species that has been introduced from Japan into Denmark for pollination of fruit trees. Megachilidae nest in burrows in soil or in pithy stems. A few species build stony mud nests. Cells of Megachilidae are made of foreign materials (leaf pieces for *Megachile* species) brought into the nest.

Sphecidae. This family in its narrow sense comprises about 70 species, four of which are alien species accidentally introduced into Western Europe from North America (*Sceliphron caementarium* and *Isodontia mexicana*) or from Asia (*S. curvatum* and *S. deforme*). Adults of most species (e.g., *Isodontia*) prey on orthopteroids but some of them, such as *Sceliphron* spp., catch Araneae. While *S. deforme* has possibly not established in the Balkans, both other species became established and threaten autochtonous species of *Sceliphron* (Cetkovic et al. 2004). While *Isodontia* puts its preys in pre-existing cavities, *Sceliphron* are mud-daubers that often built their nests in or around buildings (Bitsch and Barbier 2006, Bitsch et al. 1997).

Vespoidea

Formicidae. This family includes about 650 species in Europe, 42 of which are alien *to* Europe, one is cryptogenetic and seven are European species introduced into other areas of Europe. Ants exhibit a remarkable range of life histories. They have colonized most habitats and form colonies of variable sizes in the soil, plant debris, trees and infrastructures of human origin. The nest contains one to several reproductive females as well as workers and broods. Males are produced seasonally. Mating usually takes place outside the nest but may occur inside the nest. In Europe, the argentine ant *Linepithema humile* (Mayr) is extremely abundant throughout the Mediterranean basin, causing economic damage by fostering some hemipteran pests and upsetting the action of natural enemies; However, it may occasionally act as a beneficial natural enemy in forest ecosystems (Way et al. 1997).

Vespidae. This medium-sized family comprises 300 species in Europe classified into four subfamilies: Masarinae, Eumeninae, Polistinae and Vespinae (22 species). Vespinae are social wasps that built aerial or subterranean nests made of carton and composed of several combs protected by an envelope. Recently, a hornet species alien *to* Europe, *Vespa velutina nigrithorax,* was accidentally introduced from Asia into southern France (Haxaire et al. 2006, Villemant et al. 2006) (Figure 10.11). The European yellowjackets, *Vespula germanica* (Fabricius, 1793) and *V. vulgaris* (Linné, 1758) were introduced to Iceland from continental Europe, the last into Feroe Islands (Olafsson 1979).

For nine families the number of alien species exceeds 5% of the species known in Europe (Figure 12.1). Four of these families are small (Agaonidae, Signiphoridae, Siricidae and Sphecidae) and consequently the number of alien species is marginal. However Aphelinidae, Encyrtidae, Trichogrammatidae and Formicidae are medium-sized families comprising between 150 and 700 species and consequently the number of alien taxa is relatively important. Interestingly, the number of alien Aphelinids introduced into Europe for biological control represents about one third of the specific diversity of the family in Europe. Aphelinidae, Encyrtidae and Trichogrammatidae, three families largely used for biological control, rank among the top five in terms of proportion of alien species in the European fauna. Aphelinidae and Encyrtidae are mostly biological control agents of the three mealybug families that include most of the pest species alien to Europe (Diaspididae, Pseudococcidae and Coccidae; see Chapter 9.3). Finally, Formicidae also include a large proportion of alien species to Europe and represent a major group of alien species to Europe.

12.3. Temporal trends

First records in Europe are known for 262 of the 286 hymenopteran species alien *to* Europe (92%). Dates given here are relatively imprecise, as most species may have been introduced two to five years before they were reported. Furthermore, we did not try to check all literature and collections in order to report the dates of first interception within Europe.

The number of new records per time period shows an exponential increase in the number of alien Hymenoptera to Europe during the last 200 years (Figure 12.2). The mean number of new records of alien hymenoptera varies from less than one species per year during the period (1800–1924) to about 5 species per year between 1975 and 2000. Interestingly, we observed a decrease in the number of Hymenoptera reported during the last 10 years. This overall increase in the number of introduced species also corresponded to an increase in the number of hymenopteran families newly found in Europe.

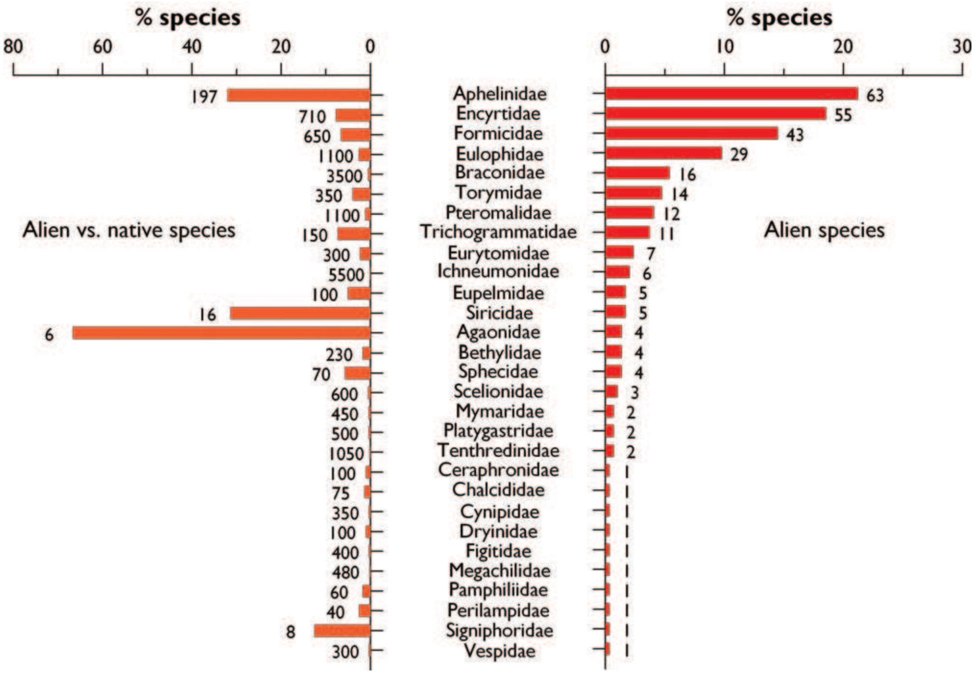

Figure 12.1. Taxonomic overview of the alien Hymenoptera. Right- Relative importance of the hymenopteran families in the alien entomofauna. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of alien species observed per family. Left- Percentage of aliens vs. total species in each Hymenoptera family in Europe. The number over each bar indicates the total number of species observed per family in Europe.

From 1800 to 1924 (125 years) only 35 species, representing 8 families, of alien hymenoptera were reported in Europe. Most of them are biological control agents or ants. Only one species of chalcid wasp (furthermore a hyperparasitoid) is reported from that period while Chalcidoidea is the most diverse group of alien Hymenoptera. However, during that period of time the European fauna was still poorly known and little studied (which is still the case for the majority of families) and the number of alien species is likely to have been underestimated. Nevertheless, over 1/3 of the alien ant species presently known in Europe were introduced between 1847 and 1929.

About 79% of the alien Hymenoptera were introduced in Europe in the last 60 years. During that period of time, 61.5% of the phytophagous alien and only 38.3% of the predator alien were introduced into Europe. Among the three most diverse families of alien Hymenoptera (namely Formicidae, Aphelinidae and Encyrtidae), Formicidae exhibited a relatively stable pattern, regarding the number of introductions per year over time, varying between 0.08 and 0.36, with a maximum of introductions during the periods 1925–1949 and 1975–1999 (Figure 12. 3). Aphelinids and encyrtids both show a relatively similar pattern, but somewhat different to the pattern exhibited by ants. These two families, largely used in biological control, showed a peak of introduc-

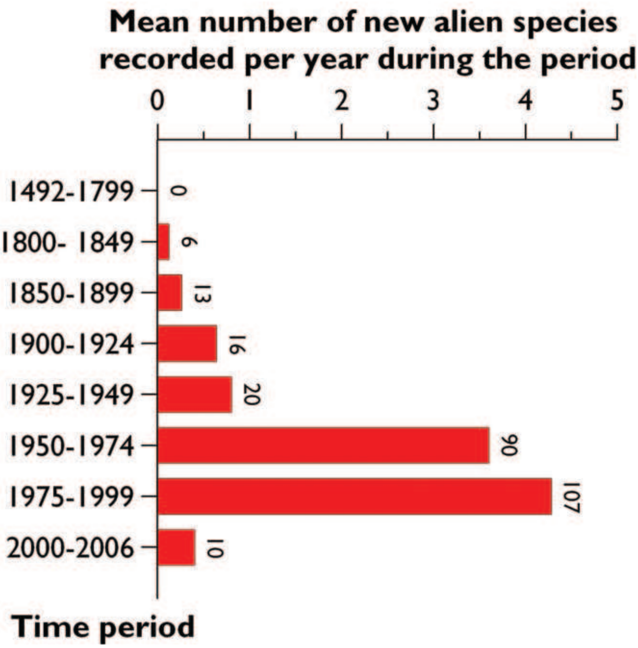

Figure 12.2. Temporal trend in number of alien Hymenoptera to Europe per period of 25 years from 1492 to 2006. Cryptogenic species excluded. The number above the bar indicates the number of species introduced.

tions during the period 1950–1999 (between 0.52 and 1.32 species per year), which roughly corresponds to the 'golden years' of biological control. More specifically, our analysis showed that 77.5% of the total number of parasitoids alien *to* Europe were introduced between 1950 and 1999. In the last 10 years, the rate of introduction drops to less than 0.1 species per year. This trend is probably due to both the decreasing interest in research on biological control and to the growing concern over possible nontarget effects of biological control.

12.4. Biogeographic patterns

Origin of alien species

We could ascertain a region of origin for 272 (95.1%) alien wasp species introduced to Europe. Overall there are no major difficulties in identifying the areas of origin of these wasps. The distribution of the genera of the hosts or the plant-hosts and also the origin of the taxonomists describing these species provide evidence of likely origins. However, for subsequent spread within Europe it is difficult, without genetic analyses, to separate spreading from adjacent countries from independent colonization events.

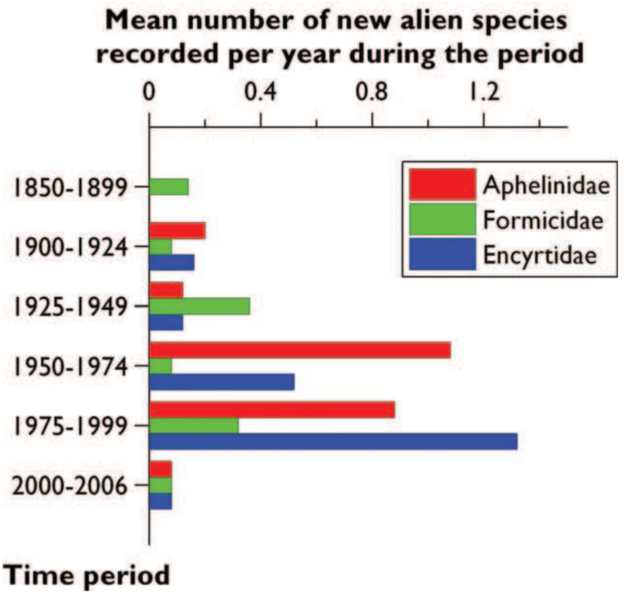

Figure 12.3. Rates of introduction of the three most diverse families of invasive Hymenoptera during the two last centuries.

North America provided the greatest part of alien Hymenoptera occurring in Europe (96 species, 35.3%), followed by Asia (84, 30.9%) and Africa (49, 18%) (Figure 12.4). This pattern is similar to the one found for Diptera (see Chapter 10) but differs from that observed in most other insect groups. Whatever the main areas of origin, trends of introduction are similar over time, and there is no evidence of a change in the origin of alien species through time (Figure 12.5). The only difference seemed to be a decrease of the afro-tropical species in the last 30 years, whereas rates of introduction still increased for both North America and Asia. However it must be noted that origins of alien species can differ from one country to another and general trends are not supported in all countries. Israel for example received more species from Asia and Africa than from North America (Roll et al. 2007).

Interestingly, the composition of the introduced guilds originating from different continents differed taxonomically. The alien guilds introduced from North America contains several phytophagous species (Siricidae, Torymidae, Eurytomidae) and several species of Ichneumonoidea that are absent from oriental invader guilds. Overall, phytophagous aliens mostly originate from North America and temperate Asia. This is the case for xylophagous Siricidae, most *Megastigmus* seed-feeders (Torymidae), several Eurytomid species. Introduced plants (e.g. *Ficus* and *Eucalyptus*) came into Europe with species of their phytophagous guilds (Agaonid and Eulophidae gall-makers). Alien Formicidae originates from Africa (10 species), Asia (14) and South America (7) while only two were introduced from North America. South American ants mostly originated from areas with Mediterranean-like climate. Parasitoid wasps originated from all continents with no particular trends.

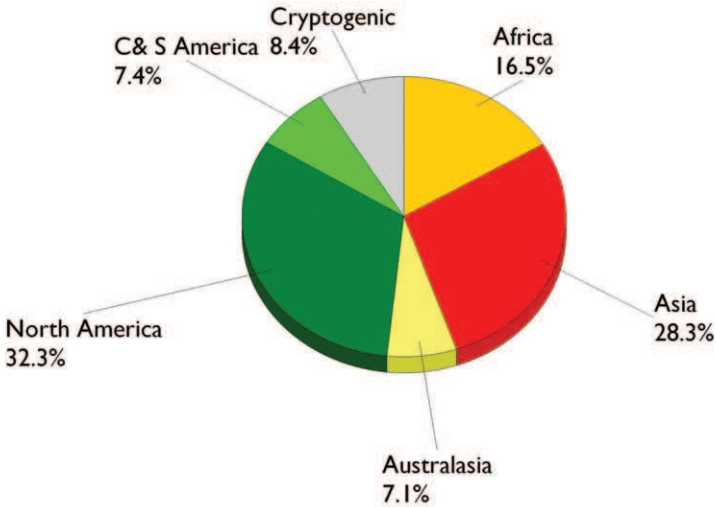

Figure 12.4. Origin of the 286 alien species of Hymenoptera established in Europe.

Distribution of alien species in Europe

Alien Hymenoptera species and families are not evenly distributed throughout Europe and large differences exist between countries (Figure 12.6, Table 12.3). However, results might have been influenced by large variations in the number of taxonomists involved, as well as by the intensity of the studies and of the samplings conducted in different regions. Little information is available for some countries of central and north-eastern Europe and consequently these areas appear to host comparatively few alien species of Hymenoptera.

Continental Italy hosts the largest number of alien Hymenoptera (144 spp.), followed by continental France (111 spp.) and continental Spain (90 spp.). Bosnia, Andorra and Latvia are the countries from which the lowest number of invasive Hymenoptera has been reported so far, with only one alien species. No correlation with the country surface area has been found but there is a latitudinal trend of decreasing number of alien species to Europe from southern to northern Europe

As most of the alien hymenopterans are biological control agents, they were mostly introduced in one or few countries by national research projects that attempted to control target pest. Large-scale European projects for biological control are rare and consequently wasps have been introduced on a local scale.

About 150 alien species (i.e., more than 50% of the total species) have been reported from only one or two countries. In contrast, 31 species are reported from at least 10 countries, among them 13 of the 36 species were introduced before 1924. These aliens mostly belong to the three diverse families of alien Hymenoptera (namely Aphelinidae, Encyrtidae and Formicidae). Most of these widespread alien wasps were parasitoids introduced for biological control. For example, *Aphelinus mali* against the woolly apple aphid, *Eriosoma lanigerum* (Hausmann); *Aphidius colemani* and *A. smithi* as generalist

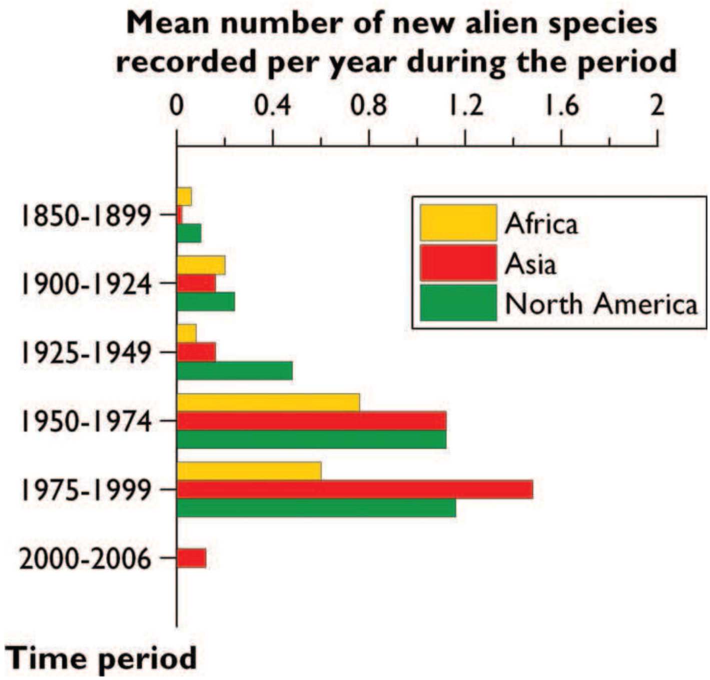

Figure 12.5. Evolution of the rate of alien Hymenoptera from different origin through time.

parasitoids used against several species of pest aphids, i.e., *Acyrthosiphon pisum* (Harris), *Aphis gossypii* Glover and *Myzus persicae* (Sulzer); *Cales noacki* against the aleyrodid *Aleurothrixus floccosus* (Maskell), a pest on *Citrus*; *Encarsia formosa* mostly as a biological control agent of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood); *Leptomastix dactylopii* Howard against *Planococcus citri* (Risso); *Aphytis mytilaspidis* as a parasitoid of the oystershell scale, *Lepidosaphes ulmi* (L.), and some other diaspidid scales; *Eretmocerus eremicus* as a parasitoid of the *Bemisia* complex (Hemiptera, Aleyrodidae) in the native range; and, *Mesopolobus spermotrophus* against the seed chalcid pest *Megastigmus spermotrophus*.

Only three of the widespread alien Hymenoptera are phytophagous and were introduced during the 19th century (*Megastigmus spermotrophus, Nematus tibialis, Sirex cyaneus*). Seven species of Formicidae appear widely distributed in Europe: *Hypoponera punctatissima* (31 countries), *Lasius neglectus* (10), *L. turcicus* (15), *Linepithema humile* (17), *Monomorium pharaonis* (23), *Paratrechina longicornis* (13), *Pheidole megacephala* (14)

12.5. Main pathways to Europe

Intentional introductions represent a large proportion of the introduced species in Europe (180 of 286, 63%) and this is mostly due to the high number of introduced

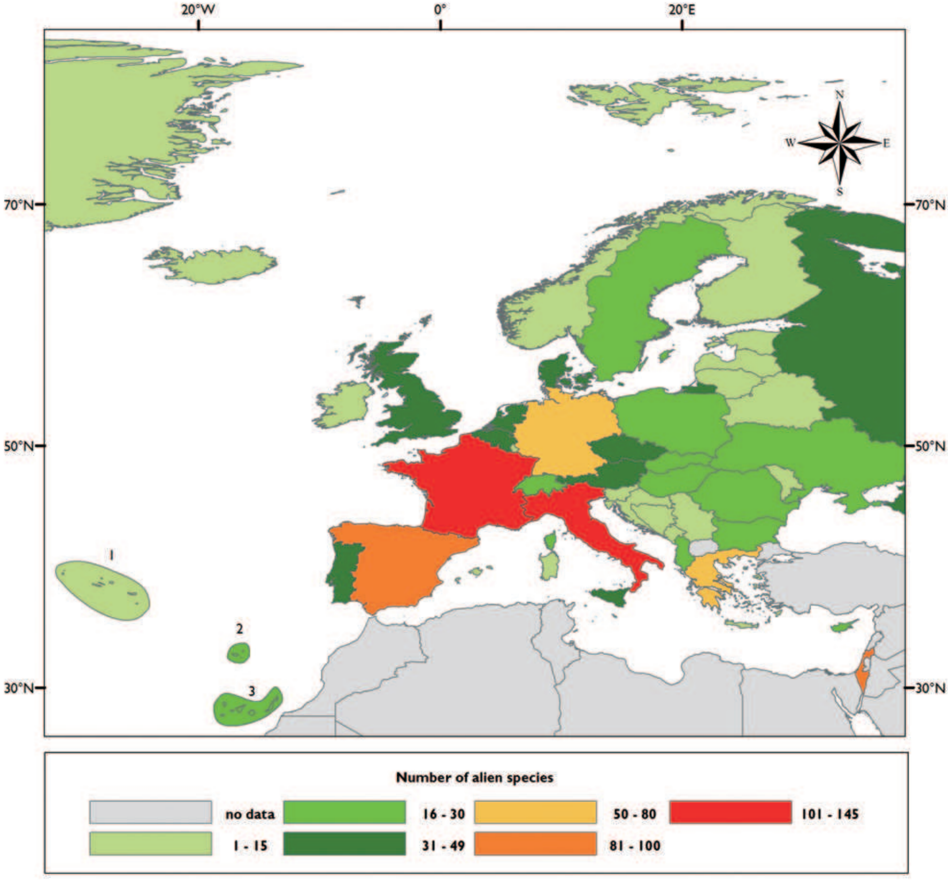

Figure 12.6. Colonization of continental European countries and main European islands by hymenopteran species alien to Europe. Archipelagos: **1** Azores **2** Madeira **3** Canary Islands.

biological control agents. Among the 106 species clearly accidentally introduced in Europe, 32 (30.1%) are phytophagous species, only 24 (22.6%) parasitoids or hyperparasitoids that were sometimes unintentionally introduced with their parasitic hosts although the real status of some of these parasitoids is difficult to ascertain, while the majority (47 species; i.e., 44.3%), are social Hymenoptera and Sphecidae.

Several species are cryptogenic and represent ancient introductions in Europe, mostly with stored products. Identifying the origin of accidental introductions is not easy but clearly introductions of plants for planting (e.g. cultivated conifers, ornamental trees) and plant seeds appeared to be the main pathways of introduction for phytophagous Hymenoptera. Thus, the lack of regulatory measures for seed imports in Europe probably resulted in the repeated establishment of alien species of *Megastigmus* seed chalcids since the beginning of the 20th century. Aliens presently represent 43% of the total fauna of tree seed chalcids in Europe (Roques and Skrzypczynska 2003). The development of trade in plant material through the Internet is likely to increase this process because there is less control, especially for tree seeds which can be moved quite freely all over the world.

12.6. Most invaded ecosystems and habitats

Most of the habitats colonized by Hymenoptera alien *to* Europe correspond to habitats strongly modified by humans (Figure 12.7). About half of the species occur in agricultural and horticultural habitats and this proportion reaches 2/3 of the species if greenhouses are considered. Only 20% of the aliens to Europe occur in woodland and forest habitats. However, the proportion is reversed if we consider Hymenoptera alien *in* Europe; in this case, half of the translocated species are phytophagous pests of trees.

12.7. Ecological and economic impact

The ecological impacts of alien invertebrate species have been recently reviewed by Kenis et al. (2009) and Hymenoptera represent well all impact categories described in this review. Biological control programmes against pests, using introduced parasitoids, were initiated in Europe about 100 years ago. These programs using relatively host-specific parasitoids are long supposed to decrease the risk to nontarget species, however there is increasing concern about the ecological costs of biological control (Louda et al. 2003, Simberloff and Stiling 1996). All introduced natural enemies present a certain

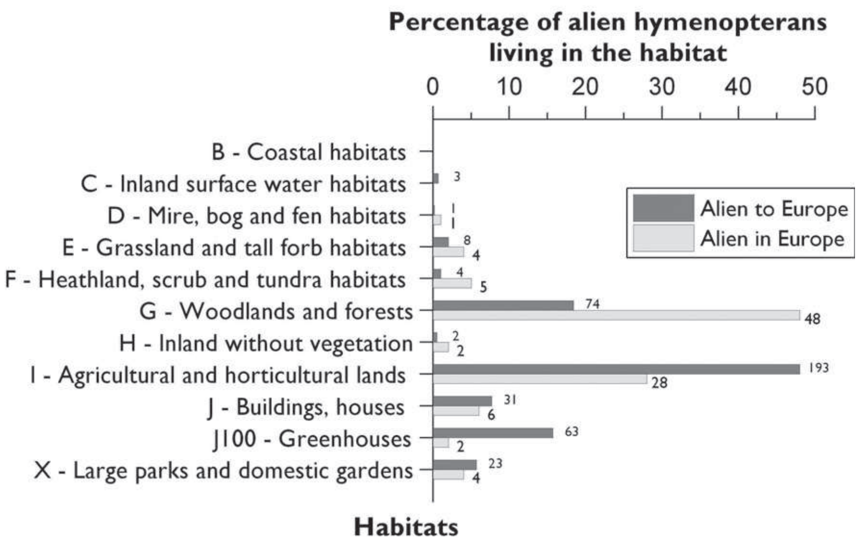

Figure 12.7. Main European habitats colonized by the species of Hymenoptera alien *to* Europe and alien *in* Europe. The number over each bar indicates the absolute number of alien hymenopterans recorded per habitat. Note that a species may have colonized several habitats.

degree of risk to non-target species and there is clear evidence of non-target effects (Lynch and Thomas 2000). Indeed, some butterfly populations have suffered a range reduction likely due to parasitism from an introduced wasp (Benson et al. 2003a, Benson et al. 2003b). Recently, Babendreier et al. (2003) found in laboratory experiments that *Trichogramma brassicae* (a parasitoid largely used against *Ostrinia nubilalis* (Hübner) on maize) parasitizes eggs of 22 out of 23 lepidopteran species tested, including several which are listed on the Swiss red list of endangered species. Because researchers have not looked systematically for non-target effects, they are probably underestimated in Europe. Biological control is potentially a valuable control strategy against invasions of alien insect pest species in agricultural and forest ecosystems. Nevertheless, post-release monitoring of biological control agents on target and nontarget species has yet to be developed. This is an ethical responsibility of scientists (Delfosse 2005) and it could help to resolve uncertainties in the impact of releases.

One of the most pernicious effects of introduced ants is the elimination or displacement of native ants and potential cascading effects on other trophic levels. Indeed, invasive ant species have huge colonies that exploit local resources and therefore represent a considerable threat to native ants. This ecological advantage of invasive ant species is partly attributed to their unicoloniality that promotes high worker densities and to the presence of several queens that accelerate colony growth and propagation

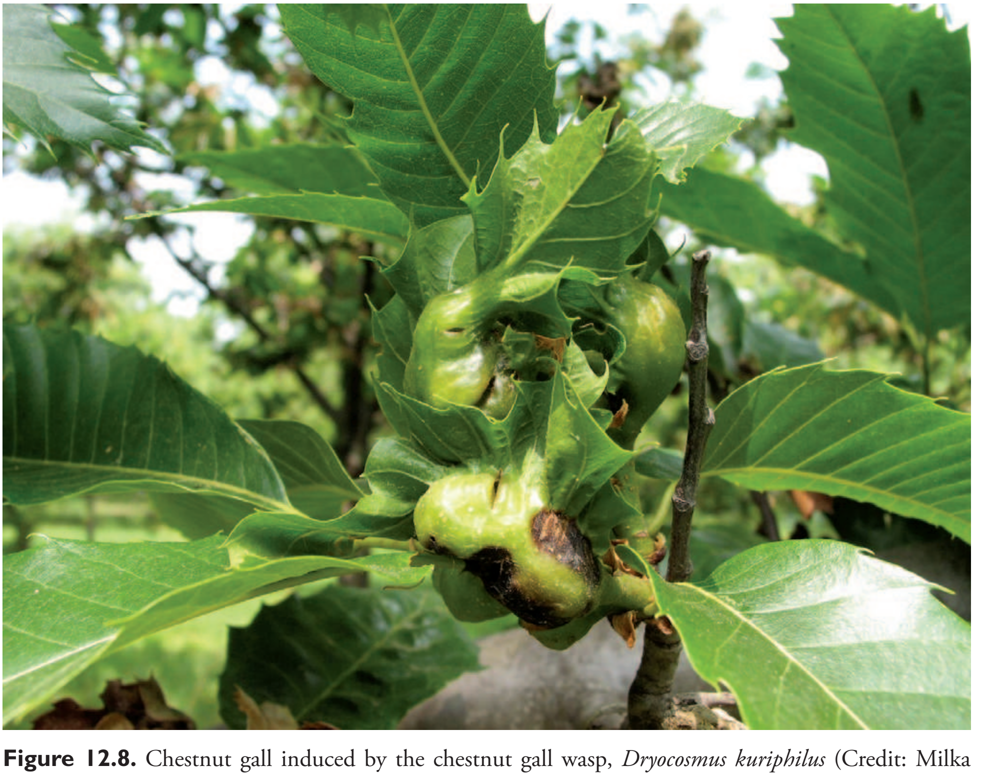

Figure 12.8. Chestnut gall induced by the chestnut gall wasp, *Dryocosmus kuriphilus* (Credit: Milka Glavendekić).

Figure 12.9. Female of cedar seed chalcid, *Megastigmus schimitscheki*, ovipositing on a cedar cone. (Credit: Gaëlle Rouault).

(Giraud et al. 2002), sometimes coupled with diet plasticity allowing them to exploit human residues.

Introduced alien parasitoids have also been suspected to displace native parasitoids by competition; however, reliable examples are still rare. One reported case in Europe is the probable displacement of *Encarsia margaritiventris* (Mercet), a parasitoid of the whiteflies *Aleurotuba jelineki* (Frauenfeld) following the introduction of *Cales noacki* (Viggiani 1994b).

There is still debate about the extent to which an introduced bee could alter native pollinator communities. Some studies clearly show that introduction of non-native bees may have strong impacts on local communities of bees (Goulson 2003), but their effects have been poorly documented in Europe. However, it is important to keep in mind that generalist *polylectic* bees (i.e. *Apis*, *Bombus*) may compete with native flower visitors (bees, wasps, butterflies, moths, beetles and flies) (Ings et al. 2006), as well as competing for nest sites. There is also evidence that introduced bees could bear pathogenic, commensal and mutualistic organisms, that could be co-introduced and transmitted to native Apidae (Goka et al. 2001). Exotic bees could also disrupt native pollinator services and could be the only pollinators of weeds, improving their seed set and spread.

Genetic impacts of Hymenoptera are clearly underestimated and there is strong risk that introduced species may hybridize with localy adapted populations. This case has been reported for *Bombus* and *Apis*, and there is a strong risk that commercial and native subspecies will hybridize with alien ones (Goulson 2003, Ings et al. 2005,

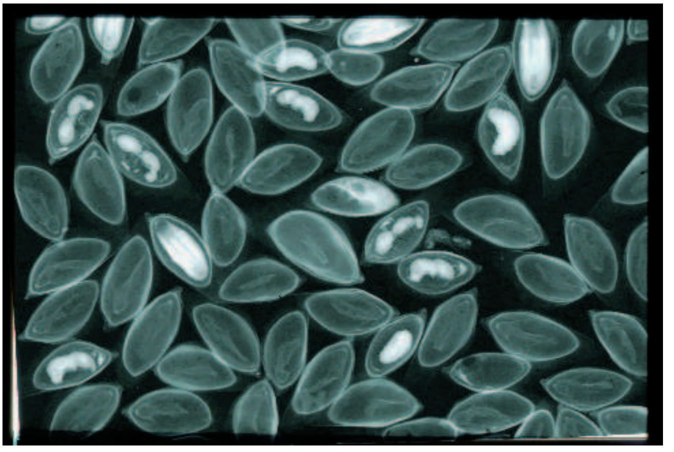

Figure 12.10. X-ray picture of Douglas fir seeds showing seeds infested by larvae and pupae of the Douglas-fir seed chalcid, *Megastigmus spermotrophus* (Credit: Jean-Paul Raimbault).

Figure 12.11. Nest of Asian Hornet, *Vespa velutina nigrothorax* (Credit: Claire Villemant)

Kanbe et al. 2008). Introduction of Mediterranean subspecies of *Apis mellifera, A. m. carnica* and *A.m. ligustica,* in northern Europe has led to extended gene flow and introgression between these subspecies and the native black honeybee, *A. m. mellifera* in different parts of Europe (De La Rùa et al. 2002, Jensen et al. 2005).

Introduced phytophagous Hymenoptera may also have strong economic and ecological impact. During mass-outbreaks they defoliate trees, reduce their growth and lead, sometimes, to their death. This is the case for diprionid outbreaks (De Somviele et al. 2004, Lyytikainen-Saarenmaa and Tomppo 2002) as well as for xylophagous siricids that threaten pine plantations (Yemshanov et al. 2009).

Economic impacts of alien Hymenoptera have received little attention In Europe and consequently are clearly underestimated. However introduced alien ant species account for over $120 billion of annual costs in the United States alone (Gutrich et al. 2007, Pimentel et al. 2000, Pimentel et al. 2005, Vis and Lenteren 2008). Introduced siricids in the United States are considered as an economically serious threat with a total projected loss of more than $ 0.76 billion over 30 years (Yemshanov et al. 2009). The recent introduction in France of Vespa velutina would also have a significant impact on beekeeping because this hornet mainly preys on honeybees (see factsheet 14.62). Additionally displacement of native bees may also lead to important economic costs that are nevertheless difficult to estimate (Allsopp et al. 2008, Gallai et al. 2009, Veddeler et al. 2008).

12.9. References

Abd-Rabou S (1999) Biological control of the cotton whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), in Egypt. *Shashpa* 6: 53–57.

Achterberg van C, Aartsen van B (1986) The European Pamphiliidae (Hymenoptera: Symphyta), with special reference to the Netherlands. *Zoologische Verhandelingen, Leiden* 234: 1–98.

Albert R, Schneller H (1994) *Eretmocerus californicus* - ein weiterer Gegenspieler der Weissen Fliege. *TASPO Gartenbau Magazin* 3: 44–45.

Alexandrakis N, Neuenschwander P (1979) Influence of road dust on *Aspidiotus nerii* Bouché (Hom. Diaspdididae) and its main parasite, *Aphytis chilensis* How. (Hym., Aphelinidae), observed on olive. *Annales de Zoologie - Écologie Animale* 11: 171–184.

Alexandrakis V, Benassy C (1981) Experiment in biological control on olive in Crete using *Aphytis melinus* DeBach (Hym. Aphelinidae), parasite of *Aspidiotus nerii* Bouche (Hom. Diaspididae). *Acta Oecologica, Oecologia Applicata* 2: 13–25.

Allsopp MH, de Lange WJ, Veldtman R (2008) Valuing insect pollination services with cost of replacement. *Plos One* 3.

Anagnou-Veroniki M, Papaioannou-Souliotis P, Karanastasi E, Giannopolitis CN (2008) New records of plant pests and weeds in Greece, 1990–2007. *Hellenic Plant Protection Journal* 1: 55–78.

Annecke DP, Mynhardt MJ (1979) On *Metaphycus stanleyi* Compere and two new species of *Metaphycus* Mercet from Africa. *Journal of the Entomological Society of Southern Africa* 42: 143–150.

Annecke DP, Mynhardt MJ (1979) On the type-species and three new species of *Prococcophagus* Silvestri from South Africa (Hymenoptera: Aphelinidae). *Journal of the Entomological Society of Southern Africa* 42: 289–297.

Annila E (1970) Host trees and emergence of *Megastigmus specularis* Walley (Hym., Torymidae). *Annales Entomologici Fennici* 36: 186–190.

Anonymous (2005) *Dryocosmus kuriphilus*. *Bulletin OEPP* 35: 422–424.

Applebaum SW, Rosen D (1964) Ecological studies on olive scale, *Parlatoria oleae* in Israel. *Journal of Economic Entomology* 57: 847–850.

Argov Y, Rössler Y (1988) Introduction of beneficial insects into Israel for the control of insect pests. *Phytoparasitica* 16: 303–315.

Argov Y, Rössler Y (1996) Introduction, release and recovery of several exotic natural enemies for biological control of the citrus leafminer, *Phyllocnistis citrella*, in Israel. *Phytoparasitica* 24: 33–38.

Argov Y, Zchori-Fein E, Rosen D (1995) Biosystematic studies in the *Aphytis lingnanensis* complex. *Israel Journal of Entomology* 29: 315–320.

Argyriou LC (1974) O.I.L.B. 'Coccoids of citrus' study group meeting in Morocco (26–31 October, 1970). *Al Awamia* 37: 57–65.

Argyriou LC, Katsoyannos P (1976) Establishment and dispersion of *Metaphycus helvolus* Compere in Kerkyra (Corfu) on *Saissettia oleae* (Olivier). *Annales de l'Institut Phytopathologique Benaki* 11: 200–208.

Argyriou LC, Kourmadas AL (1979) Notes on the biology and natural enemies of the olive tree scale *Parlatoria oleae* Colvée on olive trees in central Greece. *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* 44: 39–48.

Argyriou LC, Kourmadas AL (1980) *Ceroplastes floridensis* Comstock an important pest of citrus trees in the Aegean islands. *Fruits, Paris* 35: 705–708.

Argyriou LC, Michelakis S (1975) *Metaphycus lounsburyi* Howard (Hymenoptera: Encyrtidae), parasite nouveau de *Saissetia oleae* Berne. en Crète, Grèce. *Fruits, Paris* 30: 251–254.

Arzone A, Vidano C (1978) Introduzione in Italia di *Patasson nitens*, parassita di un nuovo nemico dell'Eucalipto. *Informatore Agrario* 34: 2741–2744.

Askew RR, Nieves Aldrey JL (2000) The genus *Eupelmus* Dalman, 1820 (Hymenoptera, Chalcidoidea, Eupelmidae) in peninsular Spain and the Canary islands, with taxonomic notes and descriptions of new species. *Graellsia* 56: 49–61.

Avidov Z, Rosen D, Gerson U (1963) A comparative study on the effects of aerial versus ground spraying of poisoned baits against the Mediterranean fruit fly on the natural enemies of scale insects in *Citrus* groves. *Entomophaga* 8: 205–212.

Babendreier D, Kuske S, Bigler F (2003) Non-target host acceptance and parasitism by *Trichogramma brassicae* Bezdenko (Hymenoptera: Trichogrammatidae) in the laboratory. *Biological Control* 26: 128–138.

Babi A, Pintureau B, Voegelé J (1984) Etude de *Trichogramma dendrolimi* (Hymenoptera: Trichogrammatidae): description d'une nouvelle sous-espèce. *Entomophaga* 29: 369–380.

Baez M, Askew RR (1999) New records of Chalcidoidea (Hymenoptera) from the Canary Islands. *Boletín de la Asociación Española de Entomología* 23: 65–82.

Bak J (1999) Injuries to seeds and cones of silver fir *Abies alba* Mill. from pests in selected stands of the Swietokrzyski National Park. *Sylwan* 143: 83–89.

Bale JS, van Lenteren JC, Bigler F (2008) Biological control and sustainable food production. *Philosophical Transactions of the Royal Society B-Biological Sciences* 363: 761–776.

Bar-Zakay I, Peleg BA, Chen C (1987) Spherical mealybug infesting citrus in Israel. *Alon Ha'notea* 41: 855–860.

Baraja MJ, Gonzalez S, Montalban C (1996) Manejo integrado en cultivo de melon entutorado bajo invernadero. *Revista de Hortalizas, Flores y Plantas Ornamentales* 113: 29–32.

Barbagallo S, Longo S, Siscaro G, Reina P, Zappalà L (2000) Status of biological control of the citrus leafminer (*Phyllocnistis citrella*) in Italy. *Abstracts, XXI International Congress of Entomology, Brazil, August 20–26, 2000* 1: 375.

Barbagallo S, Patti I, Cavalloro R (1983) *Citrus* aphids and their entomophages in Italy. *Aphid antagonists. Proceedings of a meeting of the EC Experts' Group, Portici, Italy, 23–24, November 1982.*: 116–119.

Battaglia D (1988) A note on the male of *Comperiella lemniscata* Compere and Annecke (Hymenoptera, Encyrtidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 45: 77–80.

Battaglia D, Leo Ad, Malinconico P, Rotundo G (1994) Osservazioni sulla cocciniglia bianca del pesco e del gelso in Basilicata. *Informatore Agrario* 50: 77–80.

Battisti A, Sun JH (1996) A survey of the spruce web-spinning sawflies of the genus *Cephalcia* Panzer in north-eastern China, with a guide to the identification of prepupae (Hym, Pamphiliidae). *Zeitschrift für Angewandte Entomologie* 120: 275–280.

Beardsley JW, Rasplus JY (2001) A new species of *Josephiella* (Hymenoptera: Agaonidae) forming leaf galls on *Ficus microcarpa* L. (Moraceae). *Journal of Natural History* 35: 33–40.

Bednarek A, Goszczynski W (2002) The costs of biological pest control in protected tomato crops. *Bulletin OILB. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 25: 5–8.

Ben-Dov Y (1978) Taxonomy of the nigra scale *Parasaissetia nigra* (Nietner) (Homoptera: Coccoidea: Coccidae), with observations on mass rearing and parasites of an Israeli strain. *Phytoparasitica* 6: 115–127.

Bénassy C, Bianchi H (1974) Observations sur *Aonidiella aurantii* Mask. et son parasite indigène *Comperiella bifasciata* How. (Hymenoptera, Encyrtidae). *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 3: 39–50.

Benassy C, Bianchi H, Franco E (1974) Note sur l'introduction en France d'*Aphytis lepidosaphes* (Comp.) (Hymenopt. Aphelinidae), parasite de *Lepidosaphes beckii* Newm. (Homopt., Diaspidinae). *Compte Rendu de l'Académie d'Agriculture de France* 60: 191–196.

Bénassy C, Bianchi H, Milaire H (1965) Research on the utilisation of *Prospaltella perniciosi* Tow. in France. *Annales de l'Institute National de la Recherche Agronomique (C - Annales des Épiphyties)* 15: 457–472.

Benassy C, Brun P (1989) *Encarsia elongata* Dozier (Hymenoptera, Aphelinidae), a new entomophagous species introduced in France among the citrus scale insects. *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* 54: 861–865.

Bénassy C, Mathys G, Neuffer G, Milaire H, Bianchi H et al. (1968) L'utilisation practique de *Prospaltella perniciosi* Tow. parasite du pou de San José *Quadraspidiotus perniciosus* Comst. *Entomophaga Mémoires Hors-Série* 4: 28pp.

Benassy C, Pinet C (1987) Sur l'introduction en France d'*Aphytis yanonensis* De Bach & Rosen (Hym.: Aphelinidae) parasite de la Cochenille japonaise des Citrus: *Unaspis yanonensis* Kuw. (Hom.: Diaspididae). *Compte Rendu de l'Académie d'Agriculture de France* 73: 33–38.

Bennett FD (2005) Occurrence of the eucalyptus psyllid *Ctenarytaina eucalypti* (Maskell) (Hom.: Psylloidea) and its parasitoid *Psyllaephagus pilosus* Noyes (Hym.: Encyrtidae) in the Isle of Man. *Entomologist's Record and Journal of Variation* 117: 159–163.

Benson J, Pasquale A, Van Driesche R, Elkinton J (2003) Assessment of risk posed by introduced braconid wasps to *Pieris virginiensis*, a native woodland butterfly in New England. *Biological Control* 26: 83–93.

Benson J, Van Driesche RG, Pasquale A, Elkinton J (2003) Introduced braconid parasitoids and range reduction of a native butterfly in New England. *Biological Control* 28: 197–213.

Beratlief C (1967) An important parasite of cereal weevils *Anisopteromalus calandrae* How. *Analele Institutului de Cercetari pentru Protectia Plantelor* 4: 253–254.

Bernard F (1968) Les Fourmis (Hymenoptera Formicidae) d'Europe occidentale et septentrionale. Paris: Masson et Cie. 411 pp.

Berndt O, Meyhofer R, Richter E (2007) Whitefly on cut gerbera: Biological control by parasitoids or predatory mites? *Gesunde Pflanzen* 59: 171–178.

Biermann GM (1973) Untersuchungen zur Einburgerung der nordamerikanischen Pimpline Itoplectis conquisitor (Say) (Hymenoptera:Ichneumonidae) als Parasit von Rhyacionia buoliana Den. & Schiff. (Lepidoptera:Olethreutidae) in Nordwestdeutschland.: viii+133[+131] pp.

Billany DJ, Brown RM (1980) The web spinning larch sawfly *Cephalcia lariciphila* - a new pest of *Larix* in England and Wales. *UK. Forestry (Oxford)* 53: 71–80.

Bitsch J, Barbier Y (2006) Répartition de l'espèce invasive *Sceliphron curvatum* (F.Smith) en Europe et plus particulièrement en France (Hymenoptera, Sphecidae). B*ulletin de la Société entomologique de France* 111: 227–237.

Bitsch J, Barbier Y, Gayubo F, Schmidt K, Ohl M (1997) Hyménoptères Sphecidae d'Europe occidentale. Volume 2. Faune de France 82. Paris. 429 pp.

Bjegovic PS (1962) A new method of rearing the egg-parasite of the gypsy moth, *Ooencyrtus kuwanae* How *Arhiv za Poljoprivredne Nauke, Beograd* 15(48): 105–113.

Blacker NC (2007) Ants (Hym., Formicidae) in East Anglia - Additional records from 2005. *Entomologist's Monthly Magazine* 143: 69–89.

Blumberg D (1977) Encapsulation of parasitoid eggs in soft scales (Homoptera: Coccidae). *Ecological Entomology* 2: 185–192.

Blumberg D, Wysoki M, Hadar D (1993) Further studies on the encapsulation of eggs of *Metaphycus* spp. (Hym.: Encyrtidae) by the pyriform scale, *Protopulvinaria pyriformis* (Hom.: Coccidae). *Entomophaga* 38: 7–13.

Blumberg D, Ben-Dov Y, Gross S, Drishpoun Y, Mendel Z (1999) Outbreaks and biological control of the citriculus mealybug *Pseudococcus cryptus* Hempel in Israel in the past and present - revaluation and current situation. *Alon Ha'notea* 53: 155–160.

Blumberg D, Ben-Dov Y, Mendel Z (1999) The citriculus mealybug, *Pseudococcus cryptus* Hempel, and its natural enemies in Israel: History and present situation. *Entomologica* 33: 233–242.

Boer P, Dekoninck W, van Loon AJ, Vankerkhoven F (2003) List of ants (Hymenoptera: Formicidae) of Belgium and The Netherlands, their status and Dutch vernacular names. *Entomologische Berichten* 63: 54–58.

Boer P, van Nunen F, Blommaart J, Vorst O, Huijbregts H (2006) The ant *Hypoponera punctatissima* outdoors in the Netherlands. *Entomologische Berichten* 66: 56–57.

Boer P, Vierbergen B (2008) Exotic ants in The Netherlands (Hymenoptera: Formicidae). *Entomologische Berichten* 68: 121–129.

Bogusch P, Liska P, Lukas J, Dudich A (2005) Spreading and summary of the knowledge of the invasive sphecid wasp *Sceliphron curvatum* (SMITH 1870) in the Czech Republic and Slovakia (Hymenoptera: Apocrita, Sphecidae). *Linzer Biologische Beiträge* 37: 215–221.

Boomsma JJ, Brouwer AH, Van Loon AJ (1990) A new polygynous *Lasius* species (Hymenoptera, Formicidae).II. Allozymatic confirmation of specific status. *Insectes Sociaux* 37: 363–375.

Boriani M (1991) *Chouioia cunea* Yang (Hymenoptera, Eulophidae), parasitoid of *Hyphantria cunea* (Drury) (Lepidoptera Arctiidae), new for Europe. *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 23: 193–196.

Botoc M (1971) Some Trichogrammatidae (Chalcidoidea, Trichogrammatidae) new for Romania's fauna. *Studia Universitatis Babes-Bolyai, Cluj (Ser. Biol.)* 16: 89–90.

Boucek Z (1965) Studies of European Eulophidae, IV: *Pediobius* and two allied genera (Hymenoptera). *Acta Faunistica Entomologica Musei Nationalis Pragae* 36: 5–90.

Boucek Z (1968) Contributions to the Czechoslovak fauna of Chalcidoidea (Hym.). *Acta Faunistica Entomologica Musei Nationalis Pragae* 12: 231–260.

Boucek Z (1976) African Pteromalidae (Hymenoptera); new taxa synonymies and combinations. *Journal of the Entomological Society of Southern Africa* 39(1): 9–31.

Boucek Z (1977) Descriptions of *Tachinobia* gen.n. and three new species of Tetrastichinae (Hymenoptera: Eulophidae), with a tentative key to genera. *Bulletin of Entomological Research* 67(1): 17–30.

Boucek Z (1977) A faunistic review of the Yugoslavian Chalcidoidea (Parasitic Hymenoptera). *Acta Entomologica Jugoslavica* 13 (Supplement): 1–145.

Boucek Z (1991) Four new genera of European Pteromalidae (Hymenoptera), with some taxonomic changes. *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 22: 195–206.

Bouček Z (1988) Australasian Chalcidoidea (Hymenoptera) : a biosystematic revision of genera of fourteen families, with a reclassification of species. Wallingford, Oxon, UK: CAB International. 1–832 pp.

Boucek Z, Graham MWRdV (1978) British check-list of Chalcidoidea (Hymenoptera): taxonomic notes and additions. *Entomologist's Gazette* 29: 225–235.

Boucek Z, Rasplus JY (1991) Illustrated key to West-Palearctic Genera of Pteromalidae (Hymenoptera - Chalcidoidea). In: Paris: INRA Editions, série Techniques et Pratiques, 1–140.

Branco M, Boavida C, Durand N, Franco JC, Mendel Z (2009) Presence of the Eucalyptus gall wasp *Ophelimus maskelli* and its parasitoid *Closterocerus chamaeleon* in Portugal: First record, geographic distribution and host preference. *Phytoparasitica* 37: 51–54.

Breisch H, Streito JC (2004) Oriental chestnut gall wasp: a new plague for Europe. *Infos-Ctifl*: 34–37.

Brodeur J, Boivin G (2004) Functional ecology of immature parasitoids. *Annual Review of Entomology* 49: 27–49.

Bue Pl, Colazza S (2005) *Diaspis echinocacti* (Bouché) a dangerous pest of cactus. *Informatore Fitopatologico* 55: 34–37.

Buijs MJ, Pirovano I, Lenteren JCv (1981) *Encarsia pergandiella*, a possible biological control agent for the greenhouse whitefly, *Trialeurodes vaporariorum*. A study on intra- and interspecific host selection. *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* 46: 465–475.

Burks BD (1958) A new *Bruchophagus* from liliaceous plant with a host plant list for the genus (Hymenoptera, Eurytomidae). *Proceedings of the Entomological Society of Washington* 59: 273–277.

Burnett T (1962) An effect of parasite attack on host mortality, as exemplified by *Encarsia formosa* and *Trialeurodes vaporariorum*. *Canadian Entomologist* 94: 673–679.

Cadahia D (1986) Importance des insectes ravageurs de l'eucalyptus en région méditerranéenne. *Bulletin OEPP* 16: 265–283.

Canard M, Laudeho Y (1977) Studies on a second winter generation of *Saissetia oleae in Attica* (Greece) and its reduction by *Metaphycus lounsburyi* and *Scutellista cyanea*. *Fruits, Paris* 32: 554–561.

Carniel A, Governatori G (1994) Notes on ants of Meduna River Park (Pordenone plain, North-eastern Italy). *Atti XVII Congresso Nazionale Italiano di Entomologia*: 481–482.

Carrero JM (1979) Toxicity in the field to *Cales noacki* How., a parasite of the citrus whitefly *Aleurothrixus floccosus* Mask., of several insecticides (in Spanish). *Anales del Instituto Nacional de Investigaciones Agrarias (Serie Protección Vegetal)* 1979: 75–91.

Carrero JM (1980) Current status of biological control of citrus scale-insects in Valencia (Spain). *Fruits, Paris* 35: 625–631.

Castro L (2007) New data on the spread of *Sceliphron curvatum* (Smith 1870) in the Iberian Peninsula (Hymenoptera : Sphecidae). *Boletín de la Asociación Española de Entomología*: 537–538.

Cetkovic A, Radovic I, Dorovic L (2004) Further evidence of the Asian mud-daubing wasps in Europe (Hymenoptera : Sphecidae). *Entomological Science* 7: 225–229.

Chauzat MP, Purvis G, Dunne F (2002) Release and establishment of a biological control agent, *Psyllaephagus pilosus* for eucalyptus psyllid (*Ctenarytaina eucalypti*) in Ireland. *Annals of Applied Biology* 141: 293–304.

Chumak PY (2003) The parasite of *Eretmocerus* in greenhouses of the Ukraine. *Zashchita i Karantin Rastenii* 2003: 31.

CIBC (1976) Report of work carried out during 1975. *Commonwealth Institute of Biological Control, Commonwealth Agricultural Bureaux, Slough, U.K*: 10.

Clausen CP (1978) Introduced parasites & predators of Arthropod pests and weeds: A world review. Washington D.C.: United States Department of Agriculture, Agriculture Handbook No. 480 pp.

Collingwood CA (1958) A survey of Irish Formicidae. *Proceedings of the Royal Irish Academy* 59(B): 213–219.

Collingwood CA (1993) A comparative study of the ant fauna of five Greek islands. *Biologia Gallo-Hellenica* 20: 191–197.

Collingwood CA, Hughes J (1987) Ant species in Yorkshire (England, UK). *Naturalist* 112: 95–101.

Collingwood CA, Tigar BJ, Agosti D (1997) Introduced ants in the United Arab Emirates. *Journal of Arid Environments* 37: 505–512.

Compton SG (1989) The fig wasp *Odontofroggatia galili* (Hymenoptera: Pteromalidae) in the Greek isles. *Entomologist's Gazette* 40: 183–184.

Conti E, Bin F (2000) Parasitoids of concealed noctuid eggs and their potential in biological control of Gramineae stemborers (1). *Redia*: 87–104.

Costa A, Stary P (1988) *Lysiphlebus testaceipes*, and introduced aphid parasitoid in Portugal (Hym., Aphidiidae). *Entomophaga* 33: 403–412.

Costanzi M, Frassetti F, Malausa JC (2003) Biological control of the psyllid *Ctenarytaina eucalypti* Maskell in eucalyptus plantations of Ligurian Riviera. *Informatore Fitopatologico* 53: 52–56.

Costanzi M, Malausa JC, Cocquempot C (2003) A new psyllid on the eucalyptus of the Ligurian and French Riviera: first observations of *Ctenarytaina spatulata* on southern Europe. *Phytoma*: 48–51.

Csoka G, Wittmann F, Melika G (2009) The oriental sweet chestnut gall wasp (*Dryocosmus kuriphilus* Yasumatsu, 1951) in Hungary. *Novenyvdelem* 45: 359–360.

Czechowska W, Czechowski W (1999) *Lasius neglectus* Van Loon, Boomsma & Andrásfalvy, 1990 (Hymenoptera, Formicidae), nowy dla Polski gatunek mrówki w Warszawie. *Przegląd Zoologiczny* 43: 189–191.

Czechowski W, Czechowska W (1999) New data on the occurrence of ants of the subfamily Ponerinae (Hymenoptera, Formicidae) in Poland. *Fragmenta Faunistica* 42: 7–10.

Czechowska W, Czechowski W (2003) Further record of *Lasius neglectus* Van Loon, Boomsma & Andrásfalvy (Hymenoptera: Formicidae) from Warsaw, with a key to the Polish species of the subgenus *Lasius* s.str. *Fragmenta Faunistica* 46: 195–202.

Danon V (1989) Biological control of the European corn borer, *Ostrinia nubilalis* (Hübner), by *Trichogramma pretiosum* Riley. *Zastita Bilja* 40: 131–141.

Darling DC (1999) Life history and immature stages of *Steffanolampus salicetum* (Hymenoptera: Chalcidoidea: Perilampidae). *Proceedings of the Entomological Society of Ontario* 130: 3–14.

De Haro A, Collingwood CA, Comin P (1986) Prospección mirmecológica por Ibiza y Formentera (Baleares). *Orsis* 2: 115–120.

de Jonge JT (1985) Remarkable insects in and around buildings in 1984. *Entomologische Berichten (Amsterdam)* 45: 166–168.

De La Rùa P, Serrano J, Galian J (2002) Biodiversity of *Apis mellifera* populations from Tenerife (Canary Islands) and hybridisation with East European races. *Biodiversity and Conservation* 11: 59–67.

De Somviele B, Lyytikainen-Saarenmaa P, Niemela P (2004) Sawfly (Hym., Diprionidae) outbreaks on Scots pine: effect of stand structure, site quality and relative tree position on defoliation intensity. *Forest Ecology and Management* 194: 305–317.

DeBach P (1960) The importance of taxonomy to biological control as illustrated by the cryptic history of *Aphytis holoxanthus* n. sp. (Hymenoptera: Aphelinidae), a parasite of *Chrysomphalus aonidum*, and *Aphytis coheni* n. sp., a parasite of *Aonidiella aurantii*. *Annals of the Entomological Society of America* 53: 701–705.

DeBach P, Rose M (1976) Biological control of woolly whitefly *California Agriculture* 30(5): 4–7.

DeBach P, Rosen D (1976) Chapter 6. Armoured scale insects. In: Delucchi VL (Ed) Studies in Biological Control. International Biological Programme Synthesis Series (No. 9): Cambridge University Press, 139–178.

Dekoninck W, De Baere C, Mertens J, Maelfait J-P (2002) On the arrival of the Asian invader ant *Lasius neglectus* in Belgium (Hymenoptera, Formicidae). *Bulletin et Annales de la Société Royal Entomologique de Belgique* 138: 45.

Del Bene G, Gargani E (1991) Notes on *Aleurothrixus floccosus* Mask. (Homoptera; Aleyrodidae) and its aphelinid parasitoid *Cales noacki* How. in Tuscany (in Italian). *Redia* 74: 111–126.

Del Guercio G (1925) Il pidocchio lanigera del melo ed il suo nemico endofago, *Aphelinus mali* Hald. var *italica* Del Guercio. (Continuazione, vedi num. prec.). *Agricoltura Coloniale* 19: 121–128.

Del Guercio G (1931) Il pidocchio nero ver noir o barban dell'olivo (*Phloeothrips oleae* Costa) ed i suoi rapporti con i punteruoli. *Redia* 19: 75–195.

Delanoue P (1960) Essai d'élevage artificiel permanent d'*0pius concolor* Szepl. sur un hôte intermédiaire et lâchers expérimentaux de ce parasite de *Dacus oleae* Gmel. dans les Alpes-Maritimes. *Informations Oléicoles internationales* 10: 15 p.

Delfosse ES (2005) Risk and ethics in biological control. *Biological Control* 35: 319–329.

Delvare G (1995) The family Chalcididae. In: Hanson PE, Gauld ID (Eds) The Hymenoptera of Costa Rica. Oxford: Oxford Science Publications & The Natural History Museum.

Delvare G (2006) 11.5 Familia Chalcididae. In: Hanson PE, Gauld ID (Eds) Hymenoptera de la Región Neotropical: Memoirs of the American Entomological Institute, vol. 77, 333–340.

Dessart P (1994) New or unusual Hymenoptera Ceraphronidae. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique Entomologie* 64: 49–103.

Dessart P, Cammaerts R (1995) Recapture of *Hypoponera punctatissima* in Belgium (Hymenoptera Formicidae Ponerinae). *Bulletin and Annales de la Societe Royale Belge d'Entomologie* 131: 487–489.

Domenichini G (1967) Contributo alla conoscenza biologica e tassinomica dei Tetrastichinae palearctici (Hymenoptera Eulophidae). *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 2: 75–110.

Domenichini G, Remaudière G, Delucchi V (1964) Hym. Eulophidae. Palaearctic Tetrastichinae. Paris: Le François. 101 pp.

Drost YC, Elmula AF, Posthuma-Doodeman CJAM, Van Lenteren JC (1996) Development of selection criteria for natural enemies in biological control: Parasitoids of *Bemisia argentifolii*. *Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society (N.E.V.)*: 165–170.

Dzhanokmen KA (1984) A new genus of the family Pteromalidae (Hymenoptera) from the Asian part of the USSR. *Zoologicheskiy Zhurnal* 64(1): 151–153.

Ebmer AW (1995) Hymenopterological notes from Austria: part 2 (Insecta: Hymenoptera aculeata). *Linzer Biologische Beiträge* 27: 273–277.

Edwards R (1997) Provisional atlas of the aculeate Hymenoptera of Britain and Ireland. Part 1, p. 139. Bees, Wasps and Ants Recording Society., Huntingdon: Biological Records Centre.

Eliopoulos PA, Athanasiou CG, Buchelos CH (2002) Occurrence of hymenopterous parasitoids of stored product pests in Greece. *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 25: 127–139.

Embleton AL (1902) On the economic importance of the parasites of Coccidae. *Transactions of the Royal Entomological Society of London* 35: 223.

Erdös J (1953) Additamenta ad cognitionem faunae Chalcidoidarum in Hungaria et regionibus finitimis. V. 11. Thysanidae, 12. Aphelinidae, 17. Tetracampidae, 18. Elasmidae. *Folia Entomologica Hungarica* 6: 165–184.

Erdös J (1954) Az *Eridontomerus* Crawf. nemzetség (Torymidae, Hymen.) fajai. *Allattani Közlemények* 44: 149–160.

Erdös J (1956) Additamenta ad cognitionem faunae Chalcidoidarum in Hungaria et regionibus finitimis VII. 20 Trichogrammatidae. *Folia Entomologica Hungarica* 9: 403–410.

Ermolenko VM, Sem'yanov VP (1981) Development of the fauna of sawflies (Hymenoptera, Symphyta) of man-made coenoses of cultivated lands in the south of the European part of the USSR. *Noveishie dostizheniya sel'skokhozyaistvennoi entomologii (po materialam USh s"ezda VEO, Vil'nyus, 9–13 oktyabrya 1979 g.)*: 73–76.

Espadaler X (1979) Citas nuevas o interesantes de hormigas para España. *Boletín de la Asociación Española de Entomología* 3: 95–101.

Espadaler X (1999) *Lasius neglectus* Van Loon, Boomsma & Andrásfalvy, 1990 (Hymenoptera, Formicidae), a potential pest ant in Spain. *Orsis* 14: 43–46.

Espadaler X, Bernal V (2003) Exotic ants in the Canary Islands (Hymenoptera: Formicidae). *Vieraea* 31: 1–7.

Espadaler X, Colllingwood CA (2000) Transferred ants in the Iberian peninsula (Hymenoptera, Formicidae). *Nouvelle Revue d'Entomologie* 17: 257–263.

Espadaler X, Espejo F (2002) *Tapinoma melanocephalum* (Fabricius, 1793), a new exotic ant in Spain (Hymenoptera, Formicidae). *Orsis* 17: 101–104.

Espadaler X, Lopez Soria L (1991) Rareness of certain Mediterranean ant species: fact or artifact? *Insectes Sociaux* 38: 365–377.

Faber T, Sengonca C (1997) Laboratory studies on the longevity and the fecundity of *Coccophagus scutellaris* (Dalm.) (Hym., Aphelinidae) as a parasitoid of the horse chestnut scale insect *Pulvinaria regalis* Canard (Hom., Coccidae). *Gesunde Pflanzen* 49: 84–88.

Fabre JP, Rabasse JM (1987) Introduction dans le Sud-Est de la France d'un parasite: *Pauesia cedrobii* [Hym.: Aphidiidae] du puceron: *Cedrobium laportei* [Hom.: Lachnidae] du cèdre de l'atlas: *Cedrus atlantica*. *Entomophaga* 32: 127–141.

Fabritius K (1978) Laborzucht von *Muscidifurax raptor* Gir. & Sand. (Hym. Chalcidoidea) und sein Einsatz für die biologische Bekämpfung synanthropen Fliegen. *Mitteilungen der Deutschen Gesellschaft für Allgemeine und Angewandte Entomologie* 1: 231–233.

Fabritius K (1981) Guided biological control of the synanthropic fly *Musca domestica* L. (Diptera-Muscidae) by means of the parasite *Muscidifurax raptor* Gir. & Sand. (Hymenoptera-Pteromalidae) (in Romanian with English summary). *Studii si Cercetari de Biologie* 33: 89–92.

Falco JV, Garzon-Luque E, Perez-Hinarejos M, Tarazona I, Malagon J et al. (2006) Two native pupal parasitoids of *Ceratitis capitata* (Diptera, Tephritidae) found in Spain. *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 29: 71–74.

Farrall MH, Paiva MR, Albino P (1992) Registo de uma nova especie do genero *Avetianella* (Hymenoptera, Encyrtidae) parasitoide oofago da broaca do eucalipto *Phoracantha semipunctata*. *Actas do Congresso Iberica de Entomologia* 5: 475–480.

Ferrière C (1961) Notes sur les espèces paléarctiques du genre *Prospaltella* Ashmead (Hym. Aphelinidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 34: 253–269.

Finlayson LH (1950) The biology of *Cephalonomia waterstoni* Gahan (Hym., Bethylidae) a parasite of *Loaemophloeus* (Col., Cucujidae) *Bulletin of Entomological Research* 41: 79–97.

Finzi B (1936) Risultati scientifici della spedizione di S.A.S. il principe Alessandro della Torre e tasso nell'Egitto e penisola de Sinae. *Bulletin de la Société Royale Entomologique d'Egypte* 20: 155–210.

Fitton MG, de V. Graham MWR, Boucek ZRJ, Fergusson NDM, Huddleston T et al. (1978) Hymenoptera. In: Kloet GS, Hincks WD (Eds) A checklist of British insects. Handbooks for the identification of British insects, 2nd ed. London: Royal Entomological Society of London, 1–159.

Flabbee J, Petit N, Jay N, Guenard L, Codreanu F et al. (2008) The economic costs of severe anaphylaxis in France: an inquiry carried out by the Allergy Vigilance Network. *Allergy* 63: 360–365.

Flanders SE (1969) An historical account of *Casca smithi* and its competitor *Aphytis holoxanthus*, parasites of Florida red scale. *Israel Journal of Entomology* 4: 29–40.

Forel A (1874) Les fourmis de la Suisse. Systématique. Notices anatomiques et physiologiques. Architecture. Distribution géographique. Nouvelles expériences et observations de moeurs. *Neue Denkschriften der Allgemeinen Schweizerischen Gesellschaft für die gesammten Naturwissenschaften* 26: 1–452.

Forster B, Castellazzi T, Colombi L, Furst E, Marazzi C et al. (2009) First record of the chestnut gall wasp *Dryocosmus kuriphilus* (Yasumatsu) (Hymenoptera, Cynipidae) in Southern Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 82: 271–279.

Freitag A, Dorn K, Cherix D (2000) First occurrence of the crazy ant *Paratrechina longicornis* (Latreille) (Hym. Formicidae: Formicinae) in Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 73: 301–303.

Frilli F (1965) Infested pasta. Investigations on the frequency of injurious insects and of their parasites. *Molini Ital* 7: 247–257.

Fry JM (1989) Natural enemy databank, 1987. A catalogue of natural enemies of arthropods derived from records in the CIBC Natural Enemy Databank. Wallingford, Oxford, UK CAB International. viii+185 pp.

Galil J, Eisikowitch D (1968) On the pollination ecology of *Ficus religiosa* in Israel. *Phytomorphology* 18: 356–363.

Gallai N, Salles JM, Settele J, Vaissiere BE (2009) Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68: 810–821.

Gambaro PI (1965) Observations on the bionomics of *Prospaltella perniciosi* Tow. in the Po valley. *Entomophaga* 10: 373–376.

Garonna AP (1994) On the occurrence in Italy of *Aphytis acrenulatus* Rosen & De-Bach (Hymenoptera: Aphelinidae) parasitic on *Rhizaspidiotus donacis* Leonardi (Homoptera: Diaspididae) *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 49: 53–59.

Garonna AP, Viggiani G (1989) Notizie preliminari sulla *Comperiella lemniscata* Compere; Annecke (Hymenoptera: Encyrtidae), parassitoide di *Chrysomphalus dictyospermi* (Morg.) in Italia. *Redia* 72(2): 523–527.

Garrido-Torres AM, Nieves-Aldrey JL (1990) Catalogo actualizado de los pteromalidos de la peninsula iberica e islas baleares (Hym., Chalcidoidea, Pteromalidae). *Boletín de la Asociación Española de Entomología* 14: 71–87.

Gaston KJ (1991) The magnitude of global insect species richness. *Conservation Biology* 5: 283–296.

Gauld ID, Bolton B (1988) The Hymenoptera. Oxford: Oxford University Press.

Geiter O, Homma S, Kinzelbach R (2002) Bestandsaufnahme und Bewertung von Neozoen in Deutschland. Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potentiellen Effekten gentechnisch veränderter Organismen. Berlin: Umweltbundesamt. 308 pp.

Gerling D (1966) Biological studies on *Encarsia formosa* (Hymenoptera: Aphelinidae). *Annals of the Entomological Society of America* 59: 142–143.

Gerling D, Motro U, Horowitz R (1980) Dynamics of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) attacking cotton in the coastal plain of Israel. *Bulletin of Entomological Research* 70(2): 213–219.

Gerling D, Alomar O, Arno J (2001) Biological control of *Bemisia tabaci* using predators and parasitoids. *Crop Protection* 20: 779–799.

Gerson U (1967) The natural enemies of the chaff scale, *Parlatoria pergandei* Comstock, in Israel. *Entomophaga* 12: 97–109.

Gerson U, Mescheloff E, Dubitzki E (1975) The introduction of *Neodusmetia sangwani* (Rao) (Hymenoptera: Encyrtidae) into Israel for the control of the Rhodesgrass scale, *Antonina graminis* (Maskell) (Homoptera: Pseudococcidae). *Journal of Applied Ecology* 12(3): 767–779.

Ghesquière J (1933) Sur *Diaspis visci* (Schr.) Low. et deux de ses parasites nouveaux pour la faune belge. *Bulletin et Annales de la Société Royale Entomologique de Belgique* 73: 343–349.

Gibson GAP (1995) Parasitic wasps of the subfamily Eupelminae: classification and revision of world genera (Hymenoptera: Chalcidoidea: Eupelmidae). *Memoirs on Entomology International* 5: 70–100.

Gibson GAP (2000) Differentiation of the species of *Urolepis* (Hymenoptera: Chalcidoidea: Pteromalidae), potential biocontrol, agents of filth flies (Diptera: Muscidae). *Canadian Entomologist* 132: 391–410.

Gibson GAP (2009) Revision of New World Spalangiinae (Hymenoptera: Pteromalidae). *Zootaxa*: 1–159.

Gijswijt MJ (2003) Naamlijst van de Nederlandse bronswespen (Hymenoptera: Chalcidoidea). *Nederlandse Faunistische Mededelingen* 18: 47.

Giorgini M (2001) Induction of males in thelytokous populations of *Encarsia meritoria* and *Encarsia protransvena*: a systematic tool. *BioControl* 46: 427–438.

Giraud JE, Laboulbène A (1878) Liste des éclosions d'insectes observées par le Dr. Joseph Étienne Giraud, membre honoraire. Recueillie et annotée par M. le Dr. Alexandre Laboulbène. *Annales de la Société Entomologique de France* 5: 397–436.

Giraud T, Pedersen JS, Keller L (2002) Evolution of supercolonies: The Argentine ants of southern Europe. *Proceedings of the National Academy of Sciences of the United States of America* 99: 6075–6079.

Glas M, Hassan SA (1985) Mass production and utilization of *Trichogramma*. 5. Control of two Tortricids on cereal crops, *Cnephasia longana* (Haw) and *Cnephasia pumicana* (Z.) (Lep., Tortricidae). *Zeitschrift für Angewandte Entomologie* 99: 393–399.

Glavendekic M (2000) Parasitoids and hyperparasitoids of *Agriopis* spp. (Lepidoptera: Geometridae) in Serbia. *Glasnik Sumarskog Fakulteta, Univerzitet u Beogradu*: 59–72.

Goka K, Okabe K, Yoneda M, Niwa S (2001) Bumblebee commercialization will cause worldwide migration of parasitic mites. *Molecular Ecology* 10: 2095–2099.

Gokhman VY (1996) New and little known species of the tribe Phaeogenini (Hymenoptera, Ichneumonidae) from the southern part of European Russia and adjacent territories. *Entomological Review* 75: 81–88.

Gomez K, Espadaler X (2006) Exotic ants (Hymenoptera: Formicidae) in the Balearic Islands. *Myrmecologische Nachrichten* 8: 225–233.

Gonseth Y, Imbeck P, Tussac M (2001) *Sceliphron curvatum* (Smith, 1870), une espèce nouvelle de la faune Suisse et de la faune de France (Hymenoptera Sphecidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 74: 99–103.

Gonzalez A, Martin R, Reyes MA, Jimenez I, Suarez V, et al. (2008) Pest situation and biological control of *Bemisia tabaci* in canary islands. *Journal of Insect Science* 8: 22–22.

Gonzalez Zamora JE, Moreno Vazquez R, Rodriguez Rodriguez MD, Rodriguez Rodriguez MP, Mirasol Carmona E et al. (1996) Development of parasitism of *Bemisia tabaci* (Gen.) and *Trialeurodes vaporariorum* (West.) (Homoptera: Aleyrodidae) in greenhouses in Almeria. *Boletín de Sanidad Vegetal Plagas* 22: 373–389.

Gordh G, Moczar L (1990) A catalog of the World Bethylidae (Hymenoptera: Aculeata). *Memoirs of the American Entomological Institute* 46: 1–364.

Gossner M, Liston A, Spaeth J (2007) Sawflies in the crowns of native and exotic trees, sampled with flight-interception traps in southern Germany (Hymenoptera : Symphyta). *Entomologia Generalis* 30: 273–282.

Goudey-Perrière F, Perrière C, Brousee-Gaury P (1988) Découverte de *Comperia merceti* (Compere) en région Parisienne (Hym. Chalcidoidea Encyrtidae). *Bulletin de la Société entomologique de France* 92: 160.

Goudey-Perrière F, Perrière C, Brousee-Gaury P (1991) *Comperia merceti* (Hymenoptera, Chalcidoidea, Encyrtidae) parasite des oothèques de la blatte des cuisines *Supella longipalpa* (Dictyoptera, Blattellidae). *Bulletin de la Société Zoologique de France* 116: 353–359.

Goulet H, Huber JT (1993) Hymenoptera of the World: An identification guide to families. Ottawa: Agriculture Canada pp.

Goulson D (2003) Effects of introduced bees on native ecosystems. *Annual Review of Ecology and Systematics* 34: 1–26.

Graham MWRdV (1969) The Pteromalidae of north-western Europe (Hymenoptera: Chalcidoidea). *Bulletin of the British Museum (Natural History) (Entomology) Supplement* 16: 908pp, 686 figs.

Graham MWRdV (1987) A reclassification of the European Tetrastichinae (Hymenoptera: Eulophidae), with a revision of certain genera. *Bulletin of the British Museum (Natural History) (Entomology)* 55(1): 1–392.

Graham MWRdV (1991) A reclassification of the European Tetrastichinae (Hymenoptera: Eulophidae): revision of the remaining genera. *Memoirs of the American Entomological Institute* 49: 322 pp.

Graziosi I, Santi F (2008) Chestnut gall wasp (*Dryocosmus kuriphilus*): spreading in Italy and new records in Bologna province. *Bulletin of Insectology* 61: 343–348.

Greathead DJ (1976) Mediterranean fruit fly, olive fruit fly. In: Greathead PJ (Ed) A review of biological control in western and southern Europe: Commonwealth Institute of Biological Control, Technical Communication, 37–43.

Grissell EE (1995) Toryminae (Hymenoptera: Chalcidoidea: Torymidae): a redefinition, generic classification and annotated world catalogue of species. *Memoirs on Entomology, International* 2: i-iii + 1–470.

Grissell EE (1999) An annotated catalog of World Megastigminae (Hymenoptera: Chalcidoidea: Torymidae). *Contributions of the American Entomological Institute* 31: 1–92.

Grissell EE, Prinsloo GL (2001) Seed-feeding species of *Megastigmus* (Hymenoptera: Torymidae) associated with Anacardiaceae. *Journal of Hymenoptera Research* 10: 271–279.

Grubik P (1992) New pest for Czechoslovakia of the seeds of Japanese sophora. *Byulleten' Glavnogo Botanicheskogo Sada* 165: 62–64.

Guerrieri E (1995) Influence of temperature on development and adult longevity of *Copidosoma koehleri* Blanchard (Hymenoptera: Encyrtidae) parasitoid of *Phthorimaea operculella* (Lepidoptera: Gelechiidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 50: 261–270.

Guerrieri E, Noyes J (2005) Revision of the European species of *Copidosoma* Ratzeburg (Hymenoptera: Encyrtidae), parasitoids of caterpillars (Lepidoptera). *Systematic Entomology* 30: 97–174.

Guerrieri E, Noyes JS (2000) Revision of european species of genus *Metaphycus* Mercet (Hymenoptera: Chalcidoidea: Encyrtidae), parasitoids of scale insects (Homoptera: Coccoidea). *Systematic Entomology* 25: 147–222.

Guerrieri E, Pellizzari G (2009) Parasitoids of *Pseudococcus comstocki* in Italy. *Clausenia purpurea* and *Chrysoplatycerus splendens*: first records from Europe. *Bulletin of Insectology* 62: 179–182.

Gullu M, Simsek N (1995) Studies on egg parasitoids of corn stalk borer (*Sesamia nonagrioides* Lef.) (Lep.:Noctuidae) and European corn borer (*Ostrinia nubilalis* Hbn.) (Lep.:Pyralidae) in east Mediterranean region of Turkey. *Zirai Mucadele Arastrma Yllg*: 7–8.

Gutrich JJ, VanGelder E, Loope LL (2007) Potential economic impact of introduction and spread of the red imported fire ant, *Solenopsis invicta*, in Hawaii. *Environmental Science & Policy* 10: 685–696.

Haeselbarth E (2008) On the Braconid genus *Perilitus* Nees 1818. 3rd Contribution: The species with the first segment of the *cubitus* estinguished (Hymenoptera, Braconidae). *Linzer Biologische Beiträge* 40: 1013–1152.

Hagvar ER, Hofsvang T, Trandem N (1994) The leafminer *Chromatomyia fuscula* (Diptera: Agromyzidae) and its parasitoid complex in Norwegian barley fields. *Norwegian Journal of Agricultural Sciences, Supplement* 16: 369–378.

Hansson C (1985) Taxonomy and biology of the Palaearctic species of *Chrysocharis* Forster, 1856 (Hymenoptera: Eulophidae). *Entomologica Scandinavica (supplement)* 26: 1–130.

Haxaire J, Bouquet JP, Tamisier JP (2006) *Vespa velutina* Lepeletier, 1836, une redoutable nouveauté pour la Faune de France (Hym., Vespidae). *Bulletin de la Société entomologique de France* 111: 194.

Hayes AJ (1982) *Sirex cyaneus* new record in South Scotland UK with notes on the scottish Siricidae (Hymenoptera). *Entomologist's Monthly Magazine* 118: 195–198.

Hedqvist K-J (2003) Katalog över svenska Chalcidoidea. *Entomologisk Tidskrift* 124: 101.

Hedstrom L (1987) Swedish insect records, Report 3. *Entomologisk Tidskrift* 108: 149–158.

Heimpel GE, de Boer JG (2008) Sex determination in the Hymenoptera. *Annual Review of Entomology* 53: 209–230.

Heinze J (1986) A New find of *Paratrechina longicornis* Latreille 1802 on the Azores Portugal (Hymenoptera Formicidae). *Bocagiana* 101: 1–3.

Heinze J, Trenkle S (1997) Male polymorphism and gynandromorphs in the ant *Cardiocondyla emeryi*. *Naturwissenschaften* 84: 129–131.

Hellrigl K (1984) The blue wood wasp *Sirex cyaneus* F. (Hym., Siricidae) and the dark Spruce beetle *Serropalpus barbatus* Schall (Col. Serropalpidae) as technical pests in Silver firs in South Tyrol. *Anzeiger für Schadlingskunde Pflanzenschutz Umweltschutz* 57: 33–35.

Hernández-Suárez E, Carnero A, Aguiar A, Prinsloo G, LaSalle J, et al. (2003) Parasitoids of whiteflies (Hymenoptera: Aphelinidae, Eulophidae, Platygastridae; Hemiptera: Aleyrodidae) from the Macaronesian archipelagos of the Canary Islands, Madeira and the Azores. *Systematics and Biodiversity* 1: 55–108.

Herting B (1971) Arachnida to Heteroptera. A catalogue of parasites and predators of terrestrial arthropods. Section A. Host or Prey/Enemy. 1: Commonwealth Agricultural Bureaux, Slough, England v+129 pp.

Herting B (1972) Homoptera. A catalogue of parasites and predators of terrestrial arthropods. Section A. Host or Prey/Enemy. 2: Commonwealth Agricultural Bureaux, Slough, England pp.

Herting B (1975) Lepidoptera, Part 1 (Microlepidoptera). A catalogue of parasites and predators of terrestrial arthropods. Section A. Host or Prey/Enemy. 6: Commonwealth Agricultural Bureaux, Commonwealth Institute of Biological Control pp.

Herting B (1977) Hymenoptera. A catalogue of parasites and predators of terrestrial arthropods. Section A. Host or Prey/Enemy. 4: pp.

Herting B (1978) Neuroptera, Diptera, Siphonaptera. A catalogue of parasites and predators of terrestrial arthropods. Section A. Host or Prey/Enemy: Commonwealth Agricultural Bureaux, Commonwealth Institute of Biological Control 156 pp.

Hoffer A (1970) First contribution to the knowlege of the Yugoslavian Encyrtidae (Hym., Chalcidoidea). *Studia Entomologica Forestalia* 1(10): 151–170.

Hoffer A (1982) Encyrtidae des Nationalparkes Mljet 3. Beitrag zur kenntnis der Arten der Familie Encyrtidae (Hymenoptera, Chalcidoidea) Jugoslawiens. *Acta Entomologica Jugoslavica* 18: 35–63.

Högmo (2003) Algunas especies de hormigas nuevas o interesantes para Gran Canaria, islas Canarias (Hymenoptera, Formicidae). *Vieraea* 31: 197–200.

Hogmo O (2003) Some new or interesting ants species from Gran Canaria, Canary Islands (Hymenoptera, Formicidae). *Vieraea* 31: 197–200.

Holusa J, Liska J, Modlinger R, Vele A (2007) On the occurrence of web-spinning sawflies of the genus *Cephalcia* (Hymenoptera, Pamphiliidae) in the Czech Republic. *Journal of Forest Science* 53: 57–62.

Holway DA, Lach L, Suarez AV, Tsutsui ND, Case TJ (2002) The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics* 33: 181–233.

Howard LO (1895) Revision of the Aphelininae of North America a subfamily of hymenopterous parasites of the family Chalcididae. *Technical Series, Bureau of Entomology, United States Department of Agriculture* 1: 1–44.

Howard LO (1896) The grass and grain joint-worm flies and their allies: a consideration of some north American phytophagic Eurytominae. *Bulletin. United States Department of Agriculture. Division of Entomology (Technical Series)* 2: 1–24.

Howard LO (1912) The activity of *Prospaltella berlesei* Howard against *Diaspis pentagona* Targ. in Italy. *Journal of Economic Entomology* 5: 325–328.

Huber JT (1986) Systematics, biology, and hosts of the Mymaridae and Mymarommatidae (Insecta: Hymenoptera): 1758–1984. *Entomography* 4: 185–243.

Hunter MS, Woolley JB (2001) Evolution and behavioral ecology of heteronomous aphelinid parasitoids. *Annual Review of Entomology* 46: 251–290.

Ikeda E (1996) Revision of the Japanese species of *Chrysocharis* (Hymenoptera, Eulophidae), III. *Japanese Journal of Entomology* 64: 551–569.

Ings TC, Raine NE, Chittka L (2005) Mating preference in the commercially imported bumblebee species *Bombus terrestris* in Britain (Hymenoptera : Apidae). *Entomologia Generalis* 28: 233–238.

Ings TC, Ward NL, Chittka L (2006) Can commercially imported bumble bees out-compete their native conspecifics? *Journal of Applied Ecology* 43: 940–948.

Inserra S (1971) The acclimatization, spread and biology of *Aphytis melinus* in eastern Sicily (in Italian). *Tecnica Agricola* 23: 937–941.

Jachym M (2007) Web-spinning sawflies of the genus *Cephalcia* Panzer (Hymenoptera, Pamphiliidae) in the *Picea abies* forests of the Beskidy Mountains (Poland). *Journal of Forest Science* 53: 63–68.

Janssen M (1961) Pigment modification und neuer Fundort von *Aphelinus semiflavus* How. (Hymenoptera: Chalcidoidea). *Beiträge zur Entomologie* 11: 671–678.

Japoshvili GO, Noyes JS (2006) New data on the European fauna of encyrtid wasps (Hymenoptera, Chalcidoidea, Encyrtidae). *Entomologicheskoe Obozrenie* 85: 224.

Jensen AB, Palmer KA, Boomsma JJ, Pedersen BV (2005) Varying degrees of *Apis mellifera ligustica* introgression in protected populations of the black honeybee, *Apis mellifera mellifera*, in northwest Europe. *Molecular Ecology* 14: 93–106.

Jensen TS, Ochsner P (1999) Indigenous and introduced seed chalcids in Denmark — with a revised key to the Danish species (Hymenoptera: Torymidae). *Entomologiske Meddelelser* 67: 47–56.

Jones CG, Lawton JH, Shachak M (1994) Organisms as ecological engineers. *Oikos* 69: 373–386.

Jones RA (1997) *Hypoponera punctatissima* (Roger) (Hymenoptera: Formicidae) in South-East London. *British Journal of Entomology and Natural History* 10: 256.

Jonsson M, Wratten SD, Landis DA, Gurr GM (2008) Recent advances in conservation biological control of arthropods by arthropods. *Biological Control* 45: 172–175.

Jucker C, Rigato F, Regalin R (2008) Exotic ant records from Italy (Hymenoptera, Formicidae). *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 40: 99–107.

Jussila R (1989) Ichneumonological Hymenoptera reports from Finnland V. *Notulae Entomologicae* 69: 75–80.

Kalina V (1989) Checklist of Czechoslovak Insects III (Hymenoptera). Chalcidoidea. *Acta Faunistica Entomologica Musei Nationalis Pragae* 19: 97–127.

Kanbe Y, Okada I, Yoneda M, Goka K, Tsuchida K (2008) Interspecific mating of the introduced bumblebee *Bombus terrestris* and the native Japanese bumblebee *Bombus hypocrita sapporoensis* results in inviable hybrids. *Naturwissenschaften* 95: 1003–1008.

Kavallieratos N, Lykouressis D (1999) Parasitoids (Hymenoptera Braconidae) emerged from aphids (Homoptera Aphidoidea) on citrus and their frequency in Greece. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri*: 93–104.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Pere C, et al. (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Keremidchiev M, Ganchev G, Stefan M (1980) Biology and ecology of the egg parasite *Ooencyrtus kuwanae*. *Gorskostopanska Nauka (Forest Science)* 17(4): 57–65.

Kfir R, Rosen D (1980) Parasites of soft scales (Homoptera, Coccidae) in Israel - An annotated list. *Journal of the Entomological Society of Southern Africa* 43: 113–128.

Kim IK, Mendel Z, Protasov A, Blumberg D, La Salle J (2008) Taxonomy, biology, and efficacy of two Australian parasitoids of the eucalyptus gall wasp, *Leptocybe invasa* Fisher & La Salle (Hymenoptera: Eulophidae: Tetrastichinae). *Zootaxa*: 1–20.

Kirk AA (1974) The distribution and ecology of woodwasps (Hym., Siricidae) and their parasitoid, *Rhyssa persuasoria* (L.) (Hym., Ichneumonidae), in Ireland. *Entomologist's Monthly Magazine* 110: 215–221.

Kirk AA, Lacey LA, Roditakis N, Brown JK (1993) The status of *Bemisia tabaci* (Hom.: Aleyrodidae), *Trialeurodes vaporariorum* (Hom.: Aleyrodidae) and their natural enemies in Crete. *Entomophaga* 38: 405–410.

Klotz JH, Klotz SA, Pinnas JL (2009) Animal bites and stings with anaphylactic potential. *Journal of Emergency Medicine* 36: 148–156.

Kluger J (1983) The males of *Cardiocondyla* Emery (Hymenoptera: Formicidae) with the descriptio of the winged male of *Cardiocondyla wroughtoni* (Forel). *Israel Journal of Entomology* 17: 1–21.

Kluger J (1988) The zoogeography of Israel. 9. The zoogeography of social insects of Israel and Sinai. *Monographiae Biologicae* 62: 251–275.

Konig E, Bogenschutz H (1971) Zur Bekämpfung des Kiefernknospentriebwicklers im oberrheinischen Tiefland mit und ohne DDT. *Allgemeine Forst- und Jagdzeitung* 142: 179–184.

Koponen M, Askew RR (2002) Chalcids from Madeira, Canary Islands and Azores (Hymenoptera, Chalcidoidea). *Vieraea* 30: 117.

Koscielska MK (1963) Investigation upon trophamnion *Ageniaspis fuscicollis* Dalm. (Chalcidoidea, Hymenoptera) (in Polish with English summary). *Studia Societatis Scientiarum Torunensis, Torun-Polonia (E)* 6(7): 1–9.

Kowalska T (1969) The introduction of *Encarsia formosa*, the whitefly parasite in glasshouses in Poland. *Biuletyn Instytutu Ochrony Roslin* 44: 341–352.

Kozarazhevskaya E, Mihajlovic L (1983) Biological data of mulberry scale (*Pseudaulacaspis pentagona* Targ.-Tozz.) and its parasites (Chalcidoidea) in Belgrade. *Zastita Bilja* 34: 59–75.

Krambias A, Kotzionis A (1980) Establishment of *Leptomastix dactylopii* (How.) in Cyprus. *Fruits, Paris* 35: 783–785.

Kristjansson K, Rasmussen K (1990) Pollination of the sweet pepper (*Capsicum annum* L.) with the solitary bee *Osmia cornifrons* (Radoszkowki). *Acta Horticulturae* 288: 173–179.

Kuhlmann U (1994) Spatial use by *Ageniaspis fuscicollis* of patchily distributed apple ermine moths *Yponomeuta malinellus*. *Norwegian Journal of Agricultural Sciences, Supplement* 16: 337–345.

Labeyrie V (1957) Remarque sur la mise au point d'un élevage semi-industriel de *Macrocentrus ancylivorus* Roh. *Entomophaga* 2: 271–281.

Lach L, Thomas ML (2008) Invasive ants in Australia: documented and potential ecological consequences. *Australian Journal of Entomology* 47: 275–288.

Lacordaire AI, Dussart C (2008) IBP in tomatoes: *Verticillium lecanii* in early application against whitefly. *PHM Revue Horticole*: 26–31.

LaSalle J, Gauld ID (1993) Hymenoptera: their diversity, and their impact on the diversity of other organisms. In: LaSalle J, Gauld ID (Eds) Hymenoptera and Biodiversity. Wallington, UK: CAB International, 1–26.

Laudonia S, Viggiani G (1986) Natural enemies of the Citrophilus mealybug *Pseudococcus calceolariae* Mask. in Campania, Italy. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 43: 167–172.

Laudonia S, Viggiani G (1986) Observations on the developmental stages of *Edovum puttleri* Grissell (Hymenoptera: Eulophidae), an egg-parasitoid of colorado potato beetle. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 43: 97–103.

Laudonia S, Viggiani G, Rotundo G (1991) Morphobiological data on *Telenomus busseolae* Gahan (Hymenoptera: Scelionidae), oophagous parasitoid of *Sesamia nonagrioides* (Lefevre) (Lepidoptera: Noctuidae) introduced in Italy. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 48: 125–136.

Lenteren JCv, Nell HW, Sevenster vdL, Woets J (1976) The parasite-host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae): I. Host finding by the parasite. *Entomologia Experimentalis et Applicata* 20: 123–130.

Leston AD (1988) Noteworthy Symphyta from afforested areas in Northern Ireland. *Irish Naturalists' Journal* 22: 445–447.

Liao DX, Li XL, X-F P, Chen TL (1987) Hymenoptera: Chalcidoidea (1): Economic Insect Fauna of China, 34 pp.

Limonta L, Colombo M (2003) Record of *Pheidole megacephala* (F.), *Pheidole nodus* Smith and *Tetramorium bicarinatum* Nylander (Hymenoptera Formicidae), tropical species, in nursery imported plants. *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 35: 287–289.

Linden van der A (1986) Addition of the exotic leaf miner parasites *Chrysocharis parksi* and *Opius dimidiatus* to the native Dutch parasite complex on tomato. *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* 51: 1009–1016.

Lindqvist E (1974) Taxonomic observations on several sawflies, Part 2. *Notulae Entomologicae* 54: 17–22.

Liotta G (1974) Essais d'élevage d'*Aphytis chilensis* How. (Hym. Aphelinidae). *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 3: 83–88.

Liotta G, Agro A, Pinto Ml (2003) Biological control in citrus groves in the last 50 years: three successful cases in western Sicily. *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 26: 171–173.

Liotta G, Salvia F (1991) Notizie bio-etologiche su *Comperiella bifasciata* How. (Hymenoptera: Encyrtidae) introdolta in Italia per il controllo di *Aonidiella aurantii* (Mask.) (Homoptera: Diaspididae). *Atti Congresso Nazionale Italiano di Entomologia* 16: 375–383.

Lo Verde G (2002) Ritrovamento in Italia di *Josephiella microcarpae* Beardsley & Rasplus (Hymenoptera Agaonidae) galligeno fogliare di *Ficus microcarpa* L. (Moraceae). *Naturalista Sicilia* 26: 199–203.

Lo Verde G, Porcelli F, Sinacori A (1991) Presenza di *Parapristina verticillata* (Waterst.) e *Odontofroggatia galili* Wiebes (Hymenoptera: Chalcidoidea Agaonidae) in Sicilia. *Atti Congresso Nazionale Italiano di Entomologia* 16: 139–143.

Longino JT, Cox DJ (2009) *Pheidole bilimeki* reconsidered (Hymenoptera: Formicidae). *Zootaxa* 1985: 34–42.

Longo S, Benfatto D (1982) Utilizzazione di *Leptomastix dactylopii* How. per la lotta biologica al cotonello degli agrumi in Sicilia orientale. *Informatore Agrario* 38: 19671–19672, 19675–19676.

Longo S, Palmeri V, Sommariva D (1993) Sull'attivita di *Avetianella longoi* ooparasitoïde di *Phoracantha semipunctata* nell'Italia Meridionale. *Redia* 76(1): 223–239.

Loomans AJM, Tolsma J, Heest JPNFv, Fransen JJ (1995) Releases of parasitoids (*Ceranisus* spp.) as biological control agents of western flower thrips (*Frankliniella occidentalis*) in experimental greenhouses. *Mededelingen Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen Universiteit Gent* 60: 869–877.

Lotfalizadeh H, Delvare G, Rasplus JY (2007) Phylogenetic analysis of Eurytominae based on morphological characters (Chalcidoidea: Eurytomidae). *Zoological Journal of the Linnean Society* 151: 441–510.

Louda SM, Pemberton RW, Johnson MT, Follett PA (2003) Nontarget effects - The Achilles' Heel of biological control? Retrospective analyses to reduce risk associated with biocontrol introductions. *Annual Review of Entomology* 48: 365–396.

Luppino P (1979) Lotta biologica per la difesa degli agrumeti: si controlla il *Planococcus citr*i utilizzado il *Leptomastix dactylopii*. *Informatore Agrario* 35: 4183–4186.

Lynch LD, Thomas MB (2000) Nontarget effects in the biocontrol of insects with insects, nematodes and microbial agents: the evidence *Biocontrol News and Information* 21: 117N–130N.

Lyytikainen-Saarenmaa P, Tomppo E (2002) Impact of sawfly defoliation on growth of Scots pine *Pinus sylvestris* (Pinaceae) and associated economic losses. *Bulletin of Entomological Research* 92: 137–140.

Magis N (1988) Mise à jour du catalogue des Pamphilidae observés en Belgique et dans les pays limitrophes : Hyménoptères, Symphytes. *Notes fauniques de Gembloux* 16: 1–48.

Mailleux AC, Roques A, Molenberg JM, Gregoire JC (2008) A North American invasive seed pest, *Megastigmus spermotrophus* (Wachtl) (Hymenoptera : Torymidae): Its populations and parasitoids in a European introduction zone. *Biological Control* 44: 137–141.

Maini S, Bellini R (1991) Biological control of filth flies in poultry houses by *Spalangia cameroni* Perkins (Hymenoptera: Pteromalidae). *Bollettino dell'Istituto di Entomologia "Guido Grandi" della Università degli Studi di Bologna* 45: 61–72.

Malausa JC (1999) Un espoir face aux pullulations de *Metcalfa pruinosa*. Introduction en France de *Neodryinus typhlocybae*, parasite larvaire de cette 'cicadelle'. *Phytoma* 512: 37–40.

Malausa JC, Girardet N (1997) Biological control of the blue gum psyllid. Acclimatization on the Cote d'Azur of a promising beneficial, *Psyllaephagus pilosus*. *Phytoma* 50: 49–51.

Malausa JC, Giuge L, Fauvergue X (2003) Acclimatation et dispersion en France de *N. typhlocybae* (Ashmead) (Hymenoptera, Dryinidae) introduit pour lutter contre *Metcalfa pruinosa* (Say) (Hemiptera, Flatidae). *Bulletin de la Société entomologique de France* 108: 97–102.

Malausa JC, Rabasse JM, Kreiter P (2008) Les insectes entomophages d'intérêt agricole acclimatés en France métropolitaine depuis le début du 20ème siècle. *Bulletin OEPP* 38: 136–146.

Malenotti E (1917) *Prospaltella fasciata* Malen. n. sp. *Redia* 12: 195.

Maniglia G, Agro A, Peri E (1995) Parasite activity of *Encarsia herndoni* (Girault) (Hym. Aphelinidae) on *Lepidosaphes gloverii* (Packard) (Hom. Diaspididae). *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 18: 131–135.

Manzano MR, van Lenteren JC, Cardona C (2002) Searching and oviposition behaviour of *Amitus fuscipennis*, a parasitoid of the greenhouse whitefly. *Zeitschrift für Angewandte Entomologie* 126: 528–533.

Markó B (1988) Six new ant species (Hymenoptera: Formicidae) for the Romanian myrmecofauna. *Entomologica Romanica* 3: 119–123.

Markó B, Sipos B, Csösz S, Kiss K, Boros I, et al. (2006) A comprehensive list of the ants of Romania (Hymenoptera: Formicidae). *Myrmecologische Nachrichten* 9: 65–76.

Markovic C, Stojanovic A (2008) Finding of locust sawfly *Nematus tibialis* (Newman) (Hymenoptera, Tenthredinidae) in Serbia. *Biljni Lekar* 36: 131–135.

Mary L (2005) Integrated biological control on roses under glass: overview of 5 years experimentation in Brittany. *PHM Revue Horticole*: 31–34.

Mathys G, Guignard E (1962) Un allié important dans le contrôle du pou de San José: *Prospaltella perniciosi*. *Agricoltura, Roma* 1: 59–61.

Mazzone P, Viggiani G (1983) Present status of the parasitoids of *Saissetia oleae* (Oliv.) in Italy, with preliminary biological notes on *Prococcophagus varius* Silv. and P. saissetiae Ann. and Myn. (Aphelinidae) recently introduced. *Atti XIII Congresso Nazionale Italiano di Entomologia*: 191–196.

Mei M (1995) Hymenoptera Formicidae (con diagnosis di due nuove specie). *Naturalista Sicilia* 19: 753–772.

Mendel Z, Podoler H, Rosen D (1984) Population dynamics of the mediterranean black scale, *Saissetia oleae* (Olivier), on citrus in Israel. 4. The natural enemies. *Journal of the Entomological Society of Southern Africa* 47: 3–9.

Mendel Z, Protasov A, Fisher N, La Salle J (2004) Taxonomy and biology of *Leptocybe invasa* gen. & sp n. (Hymenoptera: Eulophidae), an invasive gall inducer on Eucalyptus. *Australian Journal of Entomology* 43: 101–113.

Menteelos I (1967) *Eretmocerus corni* Hald. (Hym. Aphelinidae) parassita del *Siphoninus phillyreae* Halid. (Hom. Aleyrodidae). *Entomophaga* 12: 351–353.

Mercet RG (1911) Las plagas del naranjo en Valencia. *Asociacion espanola para el progreso de las ciencias* 4: 1–17.

Michelakis SE (1997) The citrus leafminer status in Greece. *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 20: 81–82.

Michelakis SE, Vacante V (1997) The citrus leafminer status in Greece. *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 20: 81–82.

Midtgaard F (1986) *Urocerus augur* Klug, 1803 and *Sirex cyaneus* Fabricius, 1781 (Hymenoptera Siricidae) new to the Danish fauna. *Entomologiske Meddelelser* 53: 127–129.

Mifsud D (1997) Biological control in the Maltese Islands - past initiatives and future programmes. *Bulletin de l'Organisation Européenne et Méditerranéenne pour la Protection des Plantes* 27: 77–84.

Mihajlovic L (1983) *Bruchophagus sophorae* Crosby & Crosby (Chalcidoidea: Eurytomidae), nova ursta za faunu Jugoslavije. *Zastita Bilja* 34: 419–426.

Mihalache G, Ciornei C, Tomescu R (1995) The role of parasitoid and predatory insects in limiting the outbreak of gypsy moth (*Lymantria dispar*) in the oak stands of Romania. *Biological and integrated forest protection*: 157–170.

Milanovic S, Krnjajic S, Mihajlovic L (1998) A contribution to the study of gypsy moth egg parasitoids (*Lymantria dispar* L.) in Yugoslavia. *Acta Entomologica Serbica* 3: 127–137.

Mineo G (1981) Studies on the Scelionidae (Hym. Proctotrupoidea) XIII. A revision of the Palearctic species of *Gryon* Haliday: the *muscaeformis* group. *Redia* 64: 117–147.

Mineo G, Viggiani G (1976) Sull'acclimatazione in Italia di *Leptomastix dactylopii* How. parassita del cotonella degli agrumi. *Informatore Fitopatologico* 26(5): 13–15.

Mitroiu MD (2001) Revision of the Chalcidoidea: Pteromalidae (Hymenoptera) collections of the Belgian Royal Institute of Natural Sciences and the discovery of 31 new species for Belgium. *Bulletin de la Société Royale Belge d'Entomologie* 137: 91–97.

Monaco R (1976) Nota su *Metaphycus lounsburyi* (How.) (Hym.-Encyrtidae) parassita di *Saissetia oleae* (Oliv.). *Entomologica* 12: 143–151.

Monaco R, D'Abbicco M (1987) Osservazioni biologiche sulla *Saissetia coffeae* Walk. (Rhynchota - Hom. - Coccidae) su fico (*Ficus carica* L.). *Entomologica* 22: 75–85.

Monastero S (1962) The coccids of *Citrus* in Sicily (*Lepidosaphes beckii, Parlatoria ziziphus, Coccus hesperidum, Pseudococcus adonidum, Saissetia oleae, Ceroplastes rusci* (3rd note) *Bollettino dell'Istituto di Entomologia Agraria e dell'Osservatorio di Fitopatologia di Palermo* 28: 1–87.

Montiel A, Santaella S (1995) Evolucion de la poblacion de *Saissetia oleae* Oliv en condiciones naturales. Periodos susceptibles de control biologico. *Boletín de Sanidad Vegetal Plagas* 21: 445–455.

Moscaliuc L (2009) Notes on the distribution of the genus *Plagiolepis* Mayr, 1861 (Hymenoptera: Formicidae) in Dobrogea, and the first record of *Plagiolepis obscuriscapa* Santschi, 1923 in Romania. *Travaux du Museum National d'Histoire Naturelle Grigore Antipa* 52: 297–301.

Murphy NP, Carey D, Castro LR, Dowton M, Austin AD (2007) Phylogeny of the platygastroid wasps (Hymenoptera) based on sequences from the 18S rRNA, 28S rRNA and cytochrome oxidase I genes: implications for the evolution of the ovipositor system and host relationships. *Biological Journal of the Linnean Society* 91: 653–669.

Nénon JP (1978) Synécologie d'A*geniaspis fuscicollis* Thoms. (Hyménoptère Chalcidien polyembryonnaire) parasitoïde des Hyponomeutes (Lépidoptères). *Annales de Zoologie - Ecologie Animale* 10: 525–544.

Neuffer G (1962) Zur Zucht und Verbreitung von *Prospaltella perniciosi* Tower (Hymenoptera, Aphelinidae) und anderen Parasiten der San-Jose-Schildlaus (*Quadraspidiotus perniciosus* Comstock: Homoptera, Diaspidinae) in Baden-Württemberg. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes* 14: 97–101.

Neuffer G (1968) The effectiveness of the aphelinid, *Prospaltella perniciosi* Tower in the part of southwestern Germany infested by the San José scale, *Quadraspidiotus perniciosus* (in German with English summary). *Anzeiger für Schadlingskunde Pflanzenschutz Umweltschutz* 41(7): 97–101.

Neumeyer R (2008) Ergänzungen zur Artenliste der frei lebenden Ameisen (Hymenoptera: Formicidae) in der Schweiz. *Entomo Helvetica* 1: 43–48.

Nijhof BW, Oudman L, Torres R, Garrido C (2000) The introduction of *Encarsia guadeloupae* (Hymenoptera, Aphelinidae) for control of *Aleurodicus dispersus* and *Lecanoideus floccissimus* (Homoptera, Aleyrodidae) in Tenerife. *Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society* 11: 41–47.

Noguera V, Verdu MJ, Gomez Cadenas A, Jacas JA (2003) Life cycle, dynamics and natural enemies of *Saissetia oleae* Olivier (Homoptera: Coccidae) in olive orchards in Alto Palancia (Castellon-Spain). *Boletín de Sanidad Vegetal Plagas* 29: 495–504.

Nowicki S (1940) Description of new genera and species of the family Trichogrammatidae (Hym. Chalcidoidea) from the Palaearctic region, with notes. Supplement. *Zeitschrift für Angewandte Entomologie* 26: 624–663.

Noyes JS (1988) *Copidosoma truncatellum* (Dalman) and *C. floridanum* (Ashmead) (Hymenoptera, Encyrtidae), two frequently misidentified polyembryonic parasitoids of caterpillars (Lepidoptera). *Systematic Entomology* 13: 197–204.

Noyes JS, Hayat M (1994) Oriental mealybug parasitoids of the Anagyrini (Hymenoptera: Encyrtidae). Oxon, UK CAB International. 554 pp.

Nunez-Bueno L (1982) *Trybliographa daci Weld (Hymenoptera: Cynipoidae): Biology and aspects of the relationship with its host Anastrepha suspensa (Loew) (Diptera: Tephritidae).*

Nyman T, Farrell BD, Zinovjev AG, Vikberg V (2006) Larval habits, host-plant associations, and speciation in nematine sawflies (Hymenoptera : Tenthredinidae). *Evolution* 60: 1622–1637.

Ochsner P (1998) *Seed chalcids (Megastigmus spp.) associated with firs (Abies spp.). PhD thesis*, University of Aarhus, Denmark.

Ofek G, Huberman G, Yzhar Y, Wysoki M, Kuzlitzky W*, et al.* (1997) The control of the oriental red scale, *Aonidiella orientalis* Newstead and the California red scale, *A. aurantii* (Maskell). *Alon Ha'notea* 51: 212–218.

OILB (1971) Liste d'identification des entomophages. *OILB, Genève* 8: 28.

Olafsson E (1979) A review of the species of the family Vespidae (Hymenoptera) recorded in Iceland. *Natturufraedingurinn* 49: 27–40.

Oncuer C (1974) The *Coccus* species (Homoptera: Coccidae) damaging *Citrus* groves in the Aegean region; studies on their morphological characters, distribution and natural enemies. *Bitki Koruma Bulteni*: 59 pp.

Onillon JC (1969) A propos de la présence en France d'une nouvelle espèce d'aleurode nuisible aux citrus, *Aleurothrixus floccosus* Maskell (Homoptera; Aleurodidae). *Comptes Rendus des Séances de l'Académie d'Agriculture de France* 55: 937–940.

Onillon JC (1973) Possibilités de régulation des populations d'*Aleurothrixus floccosus* Mask. (Homopt. Aleurodidae) sur agrumes par *Cales noacki* How. (Hymenopt. Aphelinidae). *Bulletin de l'Organisation Européenne et Méditerranéenne pour la Protection des Plantes* 3: 17–26.

Orphanides GM (1988) Current status of biological control of the black scale, *Saissetia oleae* (Olivier), in Cyprus. *Technical Bulletin - Agricultural Research Institute, Cyprus*: 8 pp.

Orphanides GM (1996) Establishment of *Comperiella bifasciata* (Hym.: Encyrtidae) on *Aonidiella aurantii* (Hom.: Diaspididae) in Cyprus. *Entomophaga* 41(1): 53–57.

Ortu S, Prota R (1983) Results from integrated control trials of citrus pests in Sardinia. *10th International Congress of Plant Protection 1983. Volume 3. Proceedings of a conference held at Brighton, England, 20–25 November, 1983. Plant protection for human welfare.*: 1022.

Pagliano G, Scaramozzino P, Strumia F (2000) Introduction and spread of four aculeate Hymenoptera in Italy, Sardinia and Corsica. In Austin AD, Dowton M (eds). Hymenoptera. Evolution, biodiversity and biological control. Collinwood, Australia: CSIRO Publishing, 290–295.

Panis A (1977) Variabilité infraspécifique chez *Metaphycus lounsburyi* Howard (Hymenoptera, Chalcidoidea, Encyrtidae). *Annales de Zoologie - Écologie Animale* 9: 577.

Panis A (1981) Note sur quelques insectes auxiliaires régulateurs des populations de Pseudococcidae et de Coccidae (Homoptera, Coccoidea) des agrumes en Provence orientale. *Fruits, Paris* 36: 49–52.

Panis A (1983) Biological control of the black scale *Saissetia oleae* (Olivier) in the context of integrated control in French olive cultivation. *Symbioses* 15: 63–74.

Panis A, Carrero JM, Limon F (1977) Biological note on the entomofauna of citrus trees in Spain. *Anales del Instituto Nacional de Investigaciones Agrarias (Serie Protección Vegetal)*: 139–143.

Panis A, Marro JP (1978) Variation du comportement chez *Metaphycus lounsburyi* (Hym.: Encyrtidae) (in French). *Entomophaga* 23: 9–18.

Panis A, Pinet C (1999) A discussion of some ecological factors affecting *Coccidencyrtus malloi* Blanchard (Hymenoptera: Encyrtidae) as a parasitoid of diaspidid scales under glass in France. *Entomologica* 33: 419–422.

Panis A, Pinet C (1999) A study of two *Plagiomerus* species (Hymenoptera: Encyrtidae) parasitising diaspidid scales (Coccoidea) in glasshouses in France. *Entomologica* 33: 423–427.

Papadopoulos NT, Katsoyannos BI (2003) Field parasitism of *Ceratitis capitata* larvae by *Aganaspis daci* in Chios, Greece. *BioControl* 48: 191–195.

Pappas S, Viggiani G (1979) Introdotta a Corfù la *Prospaltella lahorensis* How, (Hym. Aphelinidae), parassita del *Dialeurodes citri* (Ashm.) (Hom. Aleyrodidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 36: 38–41.

Paraskakis M, Neuenschwander P, Michelakis S (1980) *Saissetia oleae* (Oliv) (Hom. Coccidae) and its parasites on olive trees in Crete, Greece. *Zeitschrift für Angewandte Entomologie* 90: 450–464.

Peck O (1963) A catalogue of the Nearctic Chalcidoidea (Insecta: Hymenoptera). *Canadian Entomologist (Supplement)* 30: 1–1092.

Pedata PA, Viggiani G (1993) Note su *Encarsia transvena* Timberlake (Hymenoptera: Aphelinidae) parasitoide di aleirodidi nuovo per l'Italia (in Italian with English summary). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 48: 241–244.

Pedersen BV (1996) On the phylogenetic position of the Danish strain of the black honeybee (the Laeso bee), *Apis mellifera mellifera* L (Hymenoptera: Apidae) inferred from mitochondrial DNA sequences. *Entomologica Scandinavica* 27: 241–250.

Pennacchio F (1989) The Italian species of the genus *Aphidius* Nees Hymenoptera Braconidae Aphidiinae. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 46: 75–106.

Pesenko YA, Astafurova YV (2003) Annotated Bibliography of Russian and Soviet publications on the bees (Hymenoptera: Apoidea; excluding Apis mellifera): 1771–2002. *Denisia*: 3–616.

Pettersen H (1976) Parasites (Hym., Chalcidoidea) associated with bark beetles in Norway. *Norwegian Journal of Entomology* 23: 75–77.

Phillips DS (1997) *Delomerista novita* (Cresson) and *D. pfankuchi* (Brauns) (Hym., Ichneumonidae) new to Scotland. *Entomologist's Monthly Magazine* 133: 8.

Piekarczyk J, Wright A (1988) Recent additions to the Sawly fauna of Warwickshire, England UK. *Entomologist's Monthly Magazine* 124: 200.

Pimentel D, Lach L, Zuniga R, Morrison D (2000) Environmental and economic costs of nonindigenous species in the United States. *Bioscience* 50: 53–65.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien- invasive species in the United States. *Ecological Economics* 52: 273– 288.

Pina T, Martinez B, Verdu MJ (2001) Presence in the Iberian Peninsula of *Comperiella lemniscata* (Hym.: Encyrtidae) on the red citrus scale *Chrysomphalus dictyospermi* (Hemiptera: Diaspididae). *Boletin de Sanidad Vegetal, Plagas* 27: 29–34.

Pintureau B (2008) Les espèces européennes de Trichogrammes: ILV Edition pp.

Pintureau B, Fabre JP, Oliveira ML (1991) Study of two forms of *Megastigmus suspectus* Borries (Hym. Torymidae). *Bulletin de la Société entomologique de France* 95: 277–289.

Podoler H, Mazor M (1981) *Dirhinus giffardii* Silvestri (Hym.: Chalcididae) as a parasite of the mediterranean fruit fly, *Ceratitis capitata* (Wiedmann) (Dip.: Tephritidae). 2. Analysis of parasite responses. *Acta Oecologica, Oecologia Applicata* 2: 299–309.

Polaszek A, Abd-Rabou S, Huang J (1999) The Egyptian species of *Encarsia* (Hymenoptera: Aphelinidae): a preliminary review. *Zoologische Mededelingen* 73: 16.

Popescu IE (2004) Eurytomid wasps (Hymenoptera, Chalcidoidea, Eurytomidae) new for Romanian fauna (II). *Analele Ştiinţifice ale Universităţii "Al.I. Cuza" Iaşi, s. (Biologie Animală)* 50: 97–102.

Popescu IE, Fusu L (2003) Eurytomid wasps (Hymenoptera, Chalcidoidea, Eurytomidae) new for Romanian fauna. *Analele Ştiinţifice ale Universităţii "Al.I. Cuza" Iaşi, s. (Biologie Animală)* 49.

Popovici O (2005) New Scelionidae species (Hymenoptera, Platygastroidea, Scelionidae) for Romanian fauna. *Analele Ştiinţifice ale Universităţii "Al.I. Cuza" Iaşi, s. (Biologie Animală)* 51: 15–17.

Porchinsky IA (1881) Vnov otkrytye vrednye nasekomye v rossii i otchet po obsledovaniyu solomy iz raznikh mestnostey khersonskoy gub., postradavshikh ot neurozhaya. pp.24 St Petersburg.

Priore R, Viggiani G (1965) La *Contarinia sorghicola* Coq. (Diptera Cecidomyiidae) ed i suoi parassiti in Italia. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 23: 1–36.

Protasov A, Blumberg D, Brand D, La Salle J, Mendel Z (2007) Biological control of the eucalyptus gall wasp *Ophelimus maskelli* (Ashmead): Taxonomy and biology of the parasitoid species *Closterocerus chamaeleon* (Girault), with information on its establishment in Israel. *Biological Control* 42: 196–206.

Protasov A, La Salle J, Blumberg D, Brand D, Saphir N, et al. (2007) Biology, revised taxonomy and impact on host plants of *Ophelimus maskelli*, an invasive gall inducer on *Eucalyptus* spp. in the Mediterranean area. *Phytoparasitica* 35: 50–76.

Protasov A, Doganlar M, La Salle J, Mendel Z (2008) Occurrence of Two Local *Megastigmus* Species Parasitic on the *Eucalyptus* Gall Wasp *Leptocybe invasa* in Israel and Turkey. *Phytoparasitica* 36: 449–459.

Prys-Jones O, Olafsson E, Kristjansson K (1981) The Icelandic bumble bee fauna (*Bombus* Latr., Apidae) and its distributional ecology. *Journal of Apiculture Research* 20: 189–197.

Pschorn Walcher H (1991) Development and diapause of different European provenances of the pine sawfly *Neodiprion sertifer* (Geoff.) (Hym., Diprionidae) under identical outdoor conditions. *Journal of Applied Entomology* 112: 382–388.

Pschorn-Walcher H, Zinnert KD (1971) On the larval taxonomy, distribution and ecology of the European sawflies. *Zeitschrift für Angewandte Entomologie* 68: 345–366.

Quilis Pérez M (1931) Especies nuevas de Aphidiidae españoles. *Eos* 17: 25–84.

Radchenko A, Czechowski W, Czechowska W (1998) The genus *Tetramorium* Mayr (Hymenoptera, Formicidae) in Poland: A survey of species and a key for their identification. *Annales Zoologici (Warsaw)* 48: 107–118.

Radchenko A, Czechowski W, Czechowska W (1999) *Tetramorium insolens* (F. Sm.) and *Tetramorium caldarium* (Rog.) (and not *T. guineense* (F.) and *T. simillimum* (F. Sm.)) (Hymenoptera, Formicidae) in Poland. *Przegląd Zoologiczny* 43: 105–106.

Rahola P (2005) Observations sur la biologie de *Sceliphron curvatum* (Smith, 1870) dans le Gard (sud de la France) (Hymenoptera, Sphecidae) *Bulletin de la Société entomologique de France* 110: 390.

Raspi A (1988) Nota preliminare sugli entomofagi di *Saissetia oleae* (Oliv.) e di *Lichtensia viburni* Sign. presenti negli-oliveti della toscana litoranea e della Liguria occidentale. *Frustula Entomologica* 11: 119–128.

Rasplus JY (1992) Inventaire des Chalcidiens de la réserve de Scandola (Hyménoptères parasites) - Première partie. *Travaux Scientifiques du Parc Régional et Réserves Naturelles de Corse* 36: 97–108.

Rasplus JY, Kerdelhué C, Le Clainche I, Mondor G (1998) Molecular phylogeny of fig waps (Hymenoptera). Agaonidae are not monophyletic. *Compte Rendu de l'Académie des Sciences de Paris* 321: 517–527.

Rasplus JY, Carcreff E, Cornuet JM, Roques A, Austin AD, et al. (2000) Genetic structure of the cypress seed chalcid *Megastigmus wachtli* (Torymidae) within its Mediterranean distribution. *Hymenoptera. Evolution, biodiversity and biological control*: 114–130.

Reichart G (1964) Comprehensive study on the pea weevil (*Bruchus pisorum*) and its control. *Kísérletügyi Közlemények* 57: 149–168.

Remaudière G, Stary P (1993) Arrivée spontanée en région parisienne de l'hyménoptère Aphidiide *Pauesia cedrobii*, parasite du puceron du cèdre *Cedrobium laportei Revue Francaise d'Entomologie (Nouvelle Série)* 15: 157–158.

Reyes J, Espadaler X (2005) Tres nuevas especies foraneas de Hormigas para la Peninsula Ibérica (Hymenoptera, Formicidae). *Boletín Sociedad Entomológica Aragonesa* 36: 263–265.

Reyes Lopez JL, Luqque Garcia G (2003) Nuevas citas de *Monomorium andrei* SAUNDERS, 1890 (Hymenoptera: For-micidae) para la Península Ibérica y Baleares. *Boletín de la Asociación Española de Entomología* 27: 221–222.

Reyes-Lopez J, Ordonez-Urbano C, Carpintero-Ortega S (2008) Updated relation of alien species of Andalusia (southern Spain). *Boletín Sociedad Entomológica Aragonesa* 32: 81–94.

Rivera AC, Carbone SS, Andres JA (1999) Life cycle and biological control of the eucalyptus snout beetle (Coleoptera, (Coleoptera, Curculionidae) by *Anaphes nitens* (Hymenoptera, Mymaridae) in north-west Spain. *Agricultural and Forest Entomology* 1: 103–109

Rivnay T, Gerling D (1987) Aphelinidae parasitoids (Hymenoptera Chalcidoidea) of whiteflies (Hemiptera: Aleyrodidae) in Israel, with descriptions of three new species. *Entomophaga* 32: 463–475.

Rizzo MC, Lo Verde G, Rizzo R, Buccellato V, Caleca V (2006) Sicily for biological control of *Ophelimus maskelli* Ashmead (Hymenoptera Eulophidae) invasive gall inducer on eucalypt trees. *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 38: 237–248.

Roll U, Dayan T, Simberloff D (2007) Non-indigenous insect species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Ronquist F (1995) Phylogeny and early evolution of the Cynipoidea (Hymenoptera). *Systematic Entomology* 20: 309–335.

Roques A, Rabitsch W, Rasplus J-Y, Lopez-Vaamonde C, Nentwig W, et al. (2008) Alien terrestrial invertebrates of Europe. In DAISIE (ed.). Handbook of alien species in Europe: Invading Nature - Springer Series in Invasion Ecology, Springer-Verlag, 63–80.

Roques A, Skrzypczynska M (2003) Seed-infesting chalcids of the genus *Megastigmus* Dalman, 1820 (Hymenoptera: Torymidae) native and introduced to the West Palearctic region: taxonomy, host specificity and distribution. *Journal of Natural History* 37: 127–238.

Rose M, Rosen D (1992) *Eretmocerus debachi* n.sp. (Hymenoptera: Aphelinidae), an effective parasite of *Parabemisia myricae* (Homoptera: Aleyrodidae). *Israel Journal of Entomology* XXV-XXVI: 199–207.

Rose M, Zolnerowich G (1997) *Eretmocerus* Haldeman (Hymenoptera: Aphelinidae) in the United States, with descriptions of new species attacking *Bemisia* (*tabaci* complex) (Homoptera: Aleyrodidae). *Proceedings of the Entomological Society of Washington* 99: 1–27.

Rosen D (1962) An annotated list of hymenopterous parasites of citrus soft scale in Israel. *Entomophaga* 7: 349–357.

Rosen D (1965) The hymenopterous parasites of citrus armored scale in Israel (Hym. Chalcidoidea). *Annals of the Entomological Society of America* 58: 388–398.

Rosen D (1974) Current status of integrated control of *Citrus* pests in Israel. *Bulletin OEPP* 4: 363–368.

Rosen D, Alon A (1983) Taxonomic and biological studies of *Diversinervus cervantesi* (Girault) (Hymenoptera: Encyrtidae) a primary parasite of soft scale insects. *Contributions of the American Entomological Institute* 20: 336–362.

Rosen D, DeBach P (1979) Species of *Aphytis* of the World (Hymenoptera: Aphelinidae). 801 pp.

Roversi PF, Tiberi R, Covassi M (1991) *Ooencyrtus kuwanae* (Howard): presenza e numero di generazioni nell'Italia centrale (Hymenoptera: Encyrtidae). *Atti Congresso Nazionale Italiano di Entomologia* 16: 429–435.

Ruschka F (1912) Über erzogene chalcididen aus der Sammlung der K.K. Landwirt-schaftlich-bakteriologischen und Pflanzenschutzstation in Wien. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien* 62: 238–246.

Ruschka F (1921) Chalcididenstudien I. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien* 70: 234–315.

Russo A, Siscaro G (1994) *Diaspis echinocacti* pest of prickly pear in Sicily. *Informatore Agrario* 50: 73–76.

Russo A, Siscaro G, Verdone A (2000) On the presence of *Anastatus tenuipes* (Hymenoptera, Eupelmidae) in Italy. *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 32: 239–243.

Rutz DA, Axtell RC (1979) Sustained releases of *Muscidifurax raptor* (Hymenoptera: Pteromalidae) for house fly (*Musca domestica*) control in two types of caged-layer poultry houses. *Environmental Entomology* 8: 1105–1110.

Salgueiro J (2003) Catalogo dos Formicideos de Portugal continental e ilhas. *Boletín Sociedad Entomológica Aragonesa* 31: 145–171.

Sasso R, Laudonia S, Viggiani G (2008) Preliminary data on the biological control of *Ophelimus maskelli* (Ashmead) (Hymenoptera: Eulophidae) in Campania after the introduction of its antagonist *Closterocerus chamaeleon* (Girault). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 62: 51–55.

Scaramozzino PL, Pagliano G (1987) Note sulla presenza in Italia di 'Isodontia mexicana' (Saussure, 1867) (Hymenoptera, Sphecidae). *Rivista Piemontese di Storia Naturale* 8: 155–159.

Schedl W (1974) Erster nachweis der Farnblattwespe *Blasticotoma filiceti* Klug, 1834, in Österreich (Hymenoptera: Blasticotomidae). *Zeitschrift der Arbeitsgemeinschaft Österreichischer Entomologen* 25: 114–117.

Scheffer SJ, Grissell EE (2003) Tracing the geographical origin of *Megastigmus transvaalensis* (Hymenoptera: Torymidae): an African wasp feeding on a South American plant in North America. *Molecular Ecology* 12: 415–421.

Schembri S, Collingwood CA (1995) The myrmecofauna of the Maltese islands. Remarks and additions. *Bollettin della Società Entomologica Italiana* 127: 153–158.

Scheurer S, Liebig G (1998) *Tapinoma melanocephalum* Fabr. (Formicidae, Dolichoderinae) in buildings - Observations on its biology and control. *Anzeiger für Schadlingskunde Pflanzenschutz Umweltschutz* 71: 145–148.

Schnee H, Voigt D, Kaufer B (2006) Biological control of the blue gum psyllid *Ctenarytaina eucalypti* (Maskell) (Hemiptera, Psyllidae) by the encyrtid *Psyllaephagus pilosus* Noyes (Hymenoptera, Encyrtidae) a success not only in California and Western Europe but also in Saxony. *Gesunde Pflanzen* 58: 99–106.

Schultz R, Busch T (2009) The northernmost record of the invasive garden ant, *Lasius neglectus* (Hymenoptera: Formicidae). *Myrmecological News* 12: 183–186.

Schwarz M (1994) Distribution of Siricidae (woodwasps), Aulacidae, Evaniidae and Masaridae (Hymenoptera) in the county of Salzburg (Austria), with a preliminary bibliography of the hymenopterous fauna of Salzburg. *Linzer Biologische Beiträge* 26: 861–871.

Scopes NEA (1969) The economics of mass rearing *Encarsia formosa*, a parasite of the whitefly *Trialeurodes vaporariorum*, for use in commercial horticulture. *Plant Pathology* 18: 130–132.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Seifert B (1982) *Hypoponera punctatissima* (Hymenoptera Formicidae) and interresting ant species of human settlements. *Entomologische Nachrichten und Berichte* 26: 173–175.

Seifert B (1992) A taxonomic revision of the Palaearctic members of the ant subgenus *Lasius* s.str. (Hymenoptera: Formicidae). *Abhandlungen und Berichte des Naturkundemuseums Görlitz* 66: 1–67.

Seifert B (1996) Ameisen: Beobachten. Bestimmen. : Naturbuch-Verlag. Augsburg. 352 pp.

Seifert B (2000) Rapid range expansion in *Lasius neglectus* (Hymenoptera, Formicidae)- an Asian invader swamps Europe. *Deutsche Entomologische Zeitschrift* 47: 173–179.

Seifert B (2003) The ant genus *Cardiocondyla* (Insecta: Hymeoptera: Formicidae) - a taxonomic revision of the *C. elegans, C. bulgarica, C. batesii, C. nuda, C. shuckardi, C. stambuloffi, C. wroughtonii, C. emeryi*, and *C. minutior* species groups. *Annalen des Naturhistorischen Museums in Wien* 104: 203–338.

Sellenschlo U (1991) The ant *Monomorium floricola* (Jerdon 1851) (Hym Myrmicidae) imported to Germany for the 1st time. *Anzeiger für Schadlingskunde Pflanzenschutz Umweltschutz* 64: 111–115.

Serini GB (1990) Parasitoid of *Parectopa robiniella* Clemens and *Phyllonorycter robiniellus* (Clemens) (Lepidoptera Gracillariidae). *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 22: 139–149.

Sharkey M (2007) Phylogeny and classification of Hymenoptera. *Zootaxa* 1668: 521–548.

Shinohara A, Zombori L (2003) Records of pamphiliid sawflies (Hymenoptera) from the Ukrainian Carpathians, Poland and western Russia. *Folia Entomologica Hungarica* 64: 223–226.

Silvestri F (1908) Appunti sulla *Prospaltella berlesei* How. e specialmente sui primi stati del suo sviluppo. *Bollettino del Laboratorio di Zoologia Generale e Agraria, della R. Scuola Superiore d'Agricoltura* 3: 22–28.

Simberloff D, Stiling P (1996) Risks of species introduced for biological control. *Biological Conservation* 78: 185–192.

Simoes AMA, Cecilio A, Ilharco FA, Aguiar MF, Franco JC (2006) New records of hymenopteran parasitoid species from citrus orchards in Terceira Island (Azores, Portugal). *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 29: 189–193.

Simutnik SA, Pavlicek T, Nevo E (2005) The first record of *Anagyrus subflaviceps* (Hymenoptera, Encyrtidae) from Israel. *Vestnik Zoologii, Kiev* 39: 67–69, 104.

Sinacori A, Mineo G, Mineo N (1999) Observations on the phenology of postembryonal stage of *Heliothrips haemorrhoidalis* (Bouché) (Thysanoptera) and its natural antagonists. *Phytophaga* 9 (supplemento): 53–63.

Siscaro G (1992) *Avetianella longoi* sp.n. (Hymenoptera Encyrtidae) egg parasitoid of *Phoracantha semipunctata* F. (Coleoptera Cerambycidae). *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 24: 205–212.

Siscaro G, Barbagallo S, Longo S, Patti I (1997) First results on the biological and integrated control of citrus leafminer in Italy. *Informatore Fitopatologico* 47: 19–28.

Siscaro G, Longo S, Maugeri V, Reina P, Zappala L (1999) Establishment in Sicily of *Ageniaspis citricola*. *Informatore Agrario* 55: 85–86.

Siscaro G, Mazzeo G (1997) Rearing of *Ageniaspis citricola* for the biological control of *Phyllocnistis citrella*. *Informatore Agrario* 53: 61–64.

Skovgard H, Jespersen JB (1999) Activity and relative abundance of hymenopterous parasitoids that attack puparia of *Musca domestica* and *Stomoxys calcitrans* (Diptera: Muscidae) on confined pig and cattle farms in Denmark. *Bulletin of Entomological Research* 89: 263–269.

Skrzypczynska M (1989) Review of insects found in cones of *Abies alba* Mill in Poland. *Proceedings of the 3rd Cone and Seed Insects Working Party Conference, held in Victoria, British Columbia, Canada, on 26–30 June 1988.* 42–49.

Skrzypczynska M, Mazurkiewicz I (2002) Insects damaging cones and seeds of European fir *Abies alba* Mill. in the selected seed stands in the Krakow Forest Region (southern Poland). *Acta Agraria et Silvestria. Series Silvestris* 40: 67–86.

Smits van Burgst CAL (1915) A minute Hymenopteron (*Aspidiotiphagus schoeversi* n.sp.). *Tijdschrift voor Entomologie* 58: 292.

Sorvari J (2002) *Tapinoma melanocephalum* (Fabricius, 1793) (Hymenoptera: Formicidae), an imported ant species new to Finland, with observations and a taxonomic note. *Entomologist's Gazette* 53: 269–270.

Speight MCD (1979) *Anoplonyx destructor, Hemerobius pini* and *Pamphilius hortorum*, insects new for Ireland. *Irish Naturalists' Journal* 19: 302–303.

Spicciarelli R, Tranfaglia A, Battaglia D, Torraco R (1996) Biological control of *Aleurothrixus floccosus* with *Cales noacki*. *Informatore Agrario* 52: 67–70.

Stansly PA, Calvo J, Urbaneja A (2005) Release rates for control of *Bemisia tabaci* (Homoptera : Aleyrodidae) biotype "Q" with *Eretmocerus mundus* (Hymenoptera : Aphelinidae) in greenhouse tomato and pepper. *Biological Control* 35: 124–133.

Stary P (1975) *Aphidius colemanii* Viereck - its taxonomy, distribution and host range (Hymenoptera, Aphidiidae). *Acta Entomologica Bohemoslovaca* 72: 156–163.

Stary P, Michelena JM, Melia A (1985) *Lysiphlebus testaceipes* an exotic parasite of aphids and a biological control agent in Spain (Hymenoptera Aphidiidae). *Graellsia* 41: 131–136.

Stary P, Remaudiere G (1973) Some aphid parasites Hym., Aphidiidae from Spain. *Entomophaga* 18: 287–290.

Stary P, Remaudière G, Leclant F (1977) New additions of French Aphidiids (Hym) and their hosts. *Annales de la Société Entomologique de France* 13: 165–184.

Stathas GJ, Kontodimas DC (2001) Ecological data of the scale Targionia vitis on grapes in southern Greece. *Annales de l'Institut Phytopathologique Benaki* 19: 134–139.

Stavraki HG (1976) Results obtained from released of the oophagous parasites *Trichogramma* spp. against *Prays oleae* Bern. (Lep. Hyponomeutidae) over a four year period in Greece. *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* 42: 1361–1371.

Steenis MJv (1992) Suitability of *Aphis gossypii* Glov., *Macrosiphum euphorbiae* (Thom.), and *Myzus persicae* Sulz. (Hom.: Aphididae) as host for several aphid parasitoid species (Hym.: Braconidae). *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 16: 157–160.

Steffan JR (1952) Les espèces françaises du genre *Perilampus* Latr. (Hym. Perilampidae). *Bulletin de la Société entomologique de France* 57: 68–74.

Stenseth C (1976) Use of *Encarsia formosa* Gahan (Eulophidae: Hymenoptera) for the control of the glasshouse whitefly *Trialeurodes vaporariorum* (Westw.) (Homoptera: Aleurodidae) on tomatoes in greenhouses. *Forskning og Forsok i Landbruket* 27: 495–509.

Stojanova AM (1997) Species of family Eurytomidae (Hymenoptera: Chalcidoidea) known to the fauna of Bulgaria till 1996. *Plovdivski Universitet "Paisij Khilendarski" Nauchni Trudove Biologiya Animalia* 33: 23.

Stojanova AM (2004) Eurytomidae (Hymenoptera: Chalcidoidea) of the eastern Rhodopes (Bulgaria). In Beron P, Popov A (eds). Biodiversity of eastern Rhodopes (Bulgaria and Greece). Biodiversity of Bulgaria. 2. Pensoft Series Faunistica 41. Sophia, Bulgaria: Pensoft and National Museum of Natural History, 490.

Stratopoulou ET, Kapatos ET (1984) Preliminary results for the evaluation of the action of *Saissetia oleae* parasites in Corfu. *Entomologia Hellenica* 2: 3–9.

Stratopoulou ET, Kapatos ET, Viggiani G (1981) Preliminary observations on the distribution and the action of *Moranila californica* (How.) (Hymenoptera: Pteromalidae) in Corfu, a possible case of competitive displacement. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 38: 139–142.

Suarez AV, Holway DA, Case TJ (2001) Predicting patterns of spread in biological invasions dominated by jump dispersal: insights from Argentine ants. *Proceedings of the National Academy of Sciences of the United States of America* 98: 1095–1100.

Tadic MD (1964) Natural enemies of the fall webworm (*Hyphantria cunea* Dr.) in North America. *Entomophaga* 8: 245–252.

Tena-Barreda A, Garcia-Mari F (2006) Natural enemies of the black scale *Saissetia oleae* (Homoptera: Coccidae) in Valencia (Spain). *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique* 29: 47–54.

Thompson WR (1953) A catalogue of the parasites and predators of insect pests. Section 2. Host parasite catalogue. Part 2. Hosts of the Hymenoptera (Agaonidae to Braconidae). Ottawa, Ontario, Canada: Commonwealth Institute of Biological Control.

Thompson WR (1955) A catalogue of the parasites and predators of insect pests. Section 2. Host parasite catalogue, Part 3. Hosts of the Hymenoptera (Calliceratid to Evaniid): Commonwealth Agricultural Bureaux, The Commonwealth Institute of Biological Control, Ottawa, Ontario, Canada.

Thompson WR (1958) A catalogue of the parasites and predators of insect pests. Section 2. Host parasite catalogue, Part 5.: Commonwealth Agricultural Bureaux, Commonwealth Institute of Biological Control, Ottawa, Ontario, Canada.

Tinaut A, Año JL (2000) *Paratrechina longicornis* (Latreille, 1802) nueva cita para la Península Ibérica (Hymenoptera: Formicidae). *Boletín Sociedad Entomológica Aragonesa* 24: 253–254.

Tingle CCD, Copland MJW (1988) Predicting development of mealybug parasitoids *Anagyrus pseudococci, Leptomastix dactylopii,* and *Leptomastidea abnormis* under glasshouse conditions. *Entomologia Experimentalis et Applicata* 46(1): 19–28.

Tormos J, Beitia F, Bockmann EA, Asis JD (2009) The preimaginal stages and development of *Spalangia cameroni* Perkins (Hymenoptera: Pteromalidae) on *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). *Micron* 40: 646–658.

Tremblay E, Barbagallo S, Biase LMd, Monaco R, Ortu S (1978) On the presence in Italy of *Lysiphlebus testaceipes* (Cr.), a natural enemy of aphids injurious to citrus (Hymenoptera Ichneumonoidea, Homoptera Aphidoidea). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 35: 169–179.

Trjapitzin VA (1978) Hymenoptera II. Chalcidoidea 6. Eupelmidae: Opred Nasek. Evrop. Chasti SSSR. 232 pp.

Trjapitzin VA (1989) Parasitic Hymenoptera of the Fam. Encyrtidae of Palaearctics: Opredeliteli po Faune SSSR, 158 pp.

Tscharntke T, Bommarco R, Clough Y, Crist TO, Kleijn D, et al. (2007) Conservation biological control and enemy diversity on a landscape scale. *Biological Control* 43: 294–309.

Turchetto M, Villemant-Aït Lemkaden C, Vanin S (2003) Two fly parasitoids collected during an entomo-forensic investigation: the widespread *Nasonia vitripennis* (Hymnoptera Pteromalidae) and the newly recorded *Tachinaephagus zealandicus* (Hymenoptera Encyrtidae). *Bollettino della Società Entomologica Italiana* 135: 109–115.

Tussac H, Blasco-Zumeta J (1999) Especies de Chrysididae y Bethylidae (Hymenoptera: Chrysidoidea) colectadas en un sabinar de *Juniperus thurifera* l. en los Monegros (Zaragoza, España), con otras citas de interés para el mediterráneo occidental. *Lucas Mallada* 11: 197–211.

Urbaneja A, Llacer E, Tomas O, Garrido A, Jacas JA (2000) Indigenous natural enemies associated with *Phyllocnistis citrella* (Lepidoptera : Gracillariidae) in eastern Spain. *Biological Control* 18: 199–207.

van Achterberg C (1993) Revision of the subfamily Macrocentrinae Foerster (Hymenoptera: Braconidae) from the Palaearctic region. *Zoologische Verhandelingen, Leiden* 286: 1–110.

van der Vecht J (1984) Die orientalische Mauerwespe *Sceliphron curvatum* (Smith) in der Steiermark, Österreich (Hymenoptera: Sphecidae). *Entomofauna* 5: 213–219.

Van Loon AJ, Boomsma JJ, Andrásfalvy A (1990) A new polygynous *Lasius* species (Hymenoptera, Formicidae) from Central Europe. I. Description and general biology. *Insectes Sociaux* 37: 348–362.

Vaz A, Valente C, Serrao M (2000) Biological control of *Gonipterus scutellatus* (Coleoptera: Curculionidae) in Portugal. *Abstracts, XXI International Congress of Entomology, Brazil, August 20–26, 2000* 1: 42.

Veddeler D, Olschewski R, Tscharntke T, Klein AM (2008) The contribution of non-managed social bees to coffee production: new economic insights based on farm-scale yield data. *Agroforestry Systems* 73: 109–114.

Velimirovic V (1994) Natural enemies on *Coccus pseudomagnoliarum* Kuwana in coastal part of Montenegro. *Zastita Bilja* 45: 139–150.

Vercher R, Garcia Mari F, Costa Comelles J, Marzal C, Granda C (2000) Importation and establishment of parasitoids of the citrus leaf miner *Phyllocnistis citrella* (Lepidoptera: Gracillariidae). *Boletín de Sanidad Vegetal Plagas* 26: 577–591.

Vidal S (1996) Redescription and first record from Europe of the North American species *Chaenotetrastichus semiflavus* Girault, 1917 (Hymenoptera, Chalcidoidea: Eulophidae). *Entomofauna* 17: 149–152.

Vidal S (2001) Entomofauna Germanica. Band 4. Verzeichnis der Hautflügler Deutschalnds. Chalcidoidea. *Entomologische Nachrichten und Berichte Beiheft* 7: 60.

Vidano C (1968) Riuscita acclimatazione in Italia di un parassita oofago della cicalina-bufolo Americana. Studi del gruppo di lavoro del C.N.R. per la lotta integrale contro i nemici animali delle piante: XXI. *Giornale di Agricoltura, Jesi* 78: 1–6.

Vidano C, Marletto F (1972) Prospettive di liotta biologica contro il minatore di foglie di Robinia, *Parectopa robiniella*. *Annali della Facoltà di Scienze Agrarie della Università degli Studi di Torino* 7: 417–424.

Viggiani G (1975) La lotta biologica di tipo convenzionale. *Atti X Congresso Nazional Italiano di Entomologia*: 178–179.

Viggiani G (1975) Reintroduction de *Leptomastix dactylopii* How. pour la lutte biologique contre *Planococcus citri* Risso. *Fruits, Paris* 30: 259–260.

Viggiani G (1978) *Metaphycus helvolus* (Compere), a parasite of Saissetia oleae (Oliv.) and other injurious scale insects, acclimatised in Italy. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 35: 25–29.

Viggiani G (1980) *Coccophagus matsuyamensis* Ishihara (Hym. Aphelinidae), new parasite of *Coccophagus hesperidum* L. (Hom. Coccidae) in Italy. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 37: 45–59.

Viggiani G (1981) New records on releases and recoveries of *Encarsia lahorensis* (How.). *Fruits, Paris* 36(3): 186–187.

Viggiani G (1987) La specie italiane del genre *Encarsia* Foerster (Hymenoptera: Aphelinidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 44: 121–179.

Viggiani G (1994) The *Aphytis* fauna of the West Palaearctic region, with notes on their role in biological control. In: Rosen D (Ed) Advances in the Study of Aphytis. Andover, Hampshire: Intercept Ltd., 335–347.

Viggiani G (1994) Recent cases of interspecific competition between parasitoids of the family Aphelinidae (Hymenoptera: Chalcidoidea). *Norwegian Journal of Agricultural Sciences, Supplement* 16: 353–359.

Viggiani G (1997) Discovery of the male of *Amitus fuscipennis* MacGown and Nebeker (Hym. Platygasteridae), a parasitoid of *Trialeurodes vaporariorum* (Westwood) (Hom. Aleyrodidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* No. 52: 97–99.

Viggiani G (1998) Redescription of *Coccophagus gossypariae* Gahan (Hymenoptera, Aphelinidae), with notes on the preimaginal stages. *Phytophaga* 8: 39–47.

Viggiani G (1999) Variations and biological traits of *Coccophagus gossypariae* Gahan (Hymenoptera : Aphelinidae). *Biological Control* 16: 43–46.

Viggiani G, Battaglia D (1983) Osservazioni preliminari sull'*Anagyrus fusciventris* (Girault), nuovo parassita di *Pseudococcus calceolariae* (Maskell) in Italia. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 40: 109–114.

Viggiani G, Bernardo U (1996) Lotta biologica al tripide delle serre (*Heliothrips haemorrhoidalis*). *Informatore Agrario* 52: 73–75.

Viggiani G, Garonna AP (1993) Le specie italiane del complesso *Archenomus* Howard, *Archenomiscus* Nikolskaja, *Hispaniella* Mercet e *Pteroptrix* Westwood, con nuove combinazioni generiche (in Italian) (Hymenoptera: Aphelinidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 48: 57–88.

Viggiani G, Gerling D (1994) Chapter 9. Host-range increase of indigenous and introduced parasitoids. In: Narang SK, Bartlett AC, Faust RM (Ed) Application of Genetics to Arthropods of Biological Control Significance, 150.

Viggiani G, Gerling D (1994) Chapter 9. Host-range increase of indigenous and introduced parasitoids. In: Narang SK, Bartlett AC, Faust RM (Eds) Application of Genetics to Arthropods of Biological Control Significance. Boca Raton (USA): CRC Press, 147–157.

Viggiani G, Guerrieri E (1988) Le specie italiane del genere *Metaphycus* Mercet (Hymenoptera: Encyrtidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 45: 113–140.

Viggiani G, Iannaconne F (1972) Osservazioni sulla biologia e sui parassiti dei diaspini *Chrysomphalus dictyospermi* (Morg.) e *Lepidosaphes beckii* (Newm.) svolte in Campania nel trienno. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 30: 104–116.

Viggiani G, Laudonia S (1989) La specie italiane di *Trichogramma* Westwood (Hymenoptera: Trichogrammatidae), con un commento sullo stato della tassonomia del genere). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 46: 107–124.

Viggiani G, Mazzone P (1977) Introdotta in Italia la *Prospaltella lahorensis* How. per il controllo biologico di *Dialeurodes citri* (Ashm.). *Informatore Fitopatologico* 27(10): 5–7.

Viggiani G, Mazzone P (1977) Notizie preliminari sulla introduzione in Italia di *Metaphycus* aff. *stanleyi* Comp. e *Diversinerus elegans* Silv. (Hym. Encyrtidae), parassiti di *Saissetia oleae* (Oliv.). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 34: 217–222.

Viggiani G, Mazzone P (1978) Morfologia, biologia e utilizzazione di *Prospaltella lahorensis* How. (Hym. Aphelinidae), parassita esotico introdotto in Italia per la lotta biologica al *Dialeurodes citri* (Ashm.). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 35: 99–161.

Viggiani G, Mazzone P (1979) Contributi alla conoscenza morfo-biologica delle specie del complesso *Encarsia* Foerster - *Prospaltella* Ashmead (Hym. Aphelinidae). 1. Un commento sull'attuale stato, con proposte sinonimiche e descrizione di *Encarsia silvestrii* n.sp., parasita di *Bemisia citricola* Gom.Men. (Hom. Aleyrodidae). *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 36: 42–50.

Viggiani G, Nieves Aldrey JL (1993) Prima segnalazione di *Goetheana shakespearei* Girault (Hymenoptera Eulophidae), parassitoide esotico di Thysanoptera, per l'Europa. *Bollettino di Zoologia Agraria e Bachicoltura, Milano* 25: 105–108.

Viggiani G, Romagnoli R (1995) European elm scale. *Informatore Agrario* 51: 82–84.

Viitasaari M (2002) The Northern European taxa of Pamphilidae (Hymenoptera). In: Viitasaari M (Ed) Sawfly (Hymenoptera, Symphyta). I. A review of the suborder, the Western Palaearctic taxa of Xyeloidea and Pamphilioidea. Helsinki: Tremex Press Ltd., 235–358.

Viitasaari M, Midtgaard F (1989) A Contribution to the taxonomy of horntails with notes on the genus *Sirex* Linnaeus (Hymenoptera, Siricidae). *Annales Entomologici Fennici* 55: 103–110.

Villemant C, Haxaire J, Streito JC (2006) Premier bilan de l'invasion de *Vespa velutina* Lepeletier en France (Hymenoptera, Vespidae). *Bulletin de la Société entomologique de France* 111: 535–538.

Vipin S, Santoni A, Pinniger DB (1999) Infestations of insect and rodent pests in multi-occupancy dwellings in a London borough - a study to investigate factors affecting control. *Proceedings of the 3rd International Conference on Urban Pests. Czech University of Agriculture, Prague, Czech Republic, 19–22 July 1999.*: 507–514.

Vis RMJd, Lenteren JCv (2008) *Amitus fuscipennis*, an alternative to the biological control of *Trialeurodes vaporariorum* by *Encarsia formosa*? *Bulletin of Insectology* 61: 313–325.

Vitousek P, D'Antonioi CM, Loope LL, Rejmankek M, Westbrooks R (1997) Introduced species: a significant component of human caused global change. *New Zealand Journal of Ecology* 21: 1–16.

Voegelé J, Pizzol J, Babi A (1988) The overwintering of some *Trichogramma* species. *Colloques de l'INRA* 43: 275–282.

von Aderkas P, Rouault G, Wagner R, Rohr R, Roques A (2005) Seed parasitism redirects ovule development in Douglas fir. *Proceedings of the Royal Society of London Series B-Biological Sciences* 272: 1491–1496.

Walker F (1871) Notes on Chalcidiae. Part 1, Eurytomidae. *E.W. Janson, London*: 1–18.

Walton VM, Pringle KK (2002) Evaluating effectiveness of mass release of the vine mealybug (*Planococcus ficus*) parasitoid *Coccidoxenoides peregrinus* in western Cape Province vineyards, South Africa. *Proceedings of the 1st International Symposium on Biological Control of Arthropods, Honolulu, Hawaii* 14–18 January 2002.

Way MJ, Cammell ME, Paiva MR, Colligwood CA (1997) Distribution and dynamics of the argentine ant *Linepithema (Irydomirmex) humile* (Mayr) in relation to vegetation, soil conditions, topography and native competitor ants in Portugal. *Insectes Sociaux* 44: 415–433.

Wetterer JK (2009) Worldwide spread of the destroyer ant, *Monomorium destructor* (Hymenoptera: Formicidae). *Myrmecological News* 12: 97–108.

Wetterer JK (2009) Worldwide spread of the ghost ant, *Tapinoma melanocephalum* (Hymenoptera: Formicidae). *Myrmecological News* 12: 23–33.

Wetterer JK, Espadaler X, Wetterer AL, Aguin-Pombo D, Franquinho-Aguiar AM (2006) Long-term impact of exotic ants on the native ants of Madeira. *Ecological Entomology* 31: 358–368.

Wetterer JK, Espadaler X, Wetterer AL, Aguin-Pombo D, Franquinho-Aguiar AM (2007) Ants (Hymenoptera : Formicidae) of the Madeiran archipelago. *Sociobiology* 49: 265–297.

Wetterer JK, Espadaler X, Wetterer AL, Cabral SGM (2004) Native and exotic ants of the Azores (Hymenoptera: Formicidae). *Sociobiology* 44: 1–20.

Wetzel C, Dickler E (1994) Side effects of sulphur and a natural pyrethroid on *Trichogramma dendrolimi* Matsumura (Hym., Trichogrammatidae) in apple orchards. *Bulletin. Section Regionale Ouest Palaearctique, Organisation Internationale de Lutte Biologique.* 17: 123–131.

Wiebes JT (1980) The genus *Odontofroggatia* Ishii (Hymenoptera Chalcidoidea, Pteromalidae Epichrysomallinae). *Zoologische Verhandelingen, Leiden* 56: 1–6.

Wild AL (2004) Taxonomy and distribution of the Argentine ant, *Linepithema humile* (Hymenoptera : Formicidae). *Annals of the Entomological Society of America* 97: 1204–1215.

Wild AL (2007) Taxonomic revision of the ant genus *Linepithema* (Hymenoptera: Formicidae). *University of California Publications in Entomology* 126: 1–151.

Wild AL (2009) Evolution of the Neotropical ant genus *Linepithema*. *Systematic Entomology* 34: 49–62.

Winter TG (1988) *Tremex columba* L. (Hym., Siricidae) imported into Britain in elm logs. *Entomologist's Monthly Magazine* 124: 36.

Wisniowski B (1987) *Mesopolobus pinus* (Hussey, 1960 (Hym., Pteromalidae) a new parasite of *Megastigmus suspectus* Borries, 1895 (Hym., Torymidae) in Fir-seeds. *Anzeiger für Schadlingskunde Pflanzenschutz Umweltschutz* 60: 67–68.

Witmond L (2001) An addition and correction to the list of *Urocerus* species occurring in The Netherlands (Hymenoptera: Siricidae). *Entomologische Berichten* 61: 30–32.

Woets J, Linden Avd (1985) First experiments on *Chrysocharis parksi* (Hym. Eulophidae) as a parasite for leafminer control (*Liriomyza* spp., Diptera: Agromyzidae) in European greenhouse tomatoes. *Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent* 50: 763–768.

Wood BJ (1962) Natural enemies in the control of citrus pests in Cyprus. Part 2. The insectary built at Fassouri, and a preliminary report on newly imported natural enemies. *Countryman* 1962: 16–22.

Woolley JB (1988) Phylogeny and classification of the Signiphoridae (Hymenoptera: Chalcidoidea). *Systematic Entomology* 13: 465–501.

Wysoki M, Rene S, Eliahu M, Blumberg D (2000) Influence of spinosad on some hymenopterous natural enemies of avocado, citrus and other orchard pests. *Abstracts, XXI International Congress of Entomology, Brazil, August 20–26, 2000* 1: 357–363.

Yarrow IH (1967) On the Formicidae of the Azores. Report No. 51 from the Lund University Expedition in 1957 to the Azores and Madeira. *Boletim do Museu Municipal do Funchal* 21: 24–32.

Yasnosh VA (1978) Hymenoptera II. Chalcidoidea 15. Aphelinidae. *Opredeliteli po faune S.S.S.R.* 1–494.

Yefremova ZA (2002) Catalogue of the Eulophidae (Hymenoptera: Chalcidoidea) of Russia. *Linzer Biologische Beiträge* 34: 563–618.

Yemshanov D, Koch FH, McKenney DW, Downing MC, Sapio F (2009) Mapping invasive species risks with stochastic models: A cross-border United States-Canada application for *Sirex noctilio* Fabricius. *Risk Analysis* 29: 868–884.

Zerova MD (1970) A new species of the genus *Bruchophagus* Ashm. (Hymenoptera, Eurytomidae) from the south part of the USSR. *Vestnik Zoologii, Kiev* 1970: 77–79.

Zerova MD (1978) Hymenoptera II. Chalcidoidea 8. Eurytomidae Opred. Nasek. Evrop. Chasti SSSR pp.

Zinna G (1960) Esperimenti di lotta biologica contro. II. Cotonello degli agrumi (*Pseudococcus citri* (Risso)) del isola di Procida mediante l'impiego di du parassiti esotica, *Pauridia peregrina* Timb. e *Leptomastix dactylopii* How. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 18: 257–284

Zinna G (1961) Specializzazione entomoparassiti negli Aphelinidae: studio morfologico, etologico e fisiologico del *Coccophagus bivittatus* Compere, nuovo parassita del *Coccus hesperidum* L. per l'Italia. *Bollettino del Laboratorio di Entomologia Agraria Filippo Silvestri* 19: 302–358.

Table 12.1. Hymenoptera species alien *to* Europe. List and characteristics. Status: A: Alien *to* Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 01/03/2010

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Agaonidae								
Platyscapa quadraticeps (Mayr, 1885)	A	phyto-phagous	Asia	1968, IL	IL, IT	I2, G	*Ficus*	Koponen and Askew (2002), Lo Verde et al. (1991)
Eupristina verticillata Waterston, 1921	A	phyto-phagous	Asia	1991, ES-CAN	ES-CAN, IT, IT-SIC	I2, G	*Ficus*	Beardsley and Rasplus (2001), Lo Verde (2002)
Josephiella microcarpae Beardsley & Rasplus, 2001	A	phyto-phagous	Asia	1997, ES-CAN	ES-CAN, IT, IT-SIC	I2, G	Gall maker on *Ficus* leaves	Compton (1989), Lo Verde et al. (1991), Wiebes (1980)
Odontofroggatia galili Wiebes, 1980	A	phyto-phagous	Asia	1979, GR-SEG	GR-SEG, IL, IT, IT-SIC	I2, G	*Ficus*	Galil and Eisikowitch (1968)
Aphelinidae								
Ablerus chionaspidis (Howard, 1914)	A	parasitic/ predator	Asia	1972, IT	ES, IL, IT, RS,	G4	Diaspidid scale insects (Hyperparasitoid and parasitoid)	Herting (1972), Herting (1977), Ofek et al. (1997)
Ablerus clisiocampae (Ashmead, 1894)	A	parasitic/ predator	Asia	1953, FR	FR, IT	G4	Diaspidid scale insects and lepidopteran eggs (Hyperparasitoid and parasitoid both of)	Peck (1963), Yasnosh (1978)
Ablerus perspeciosus Girault, 1916	A	parasitic/ predator	Asia	1972, FR	FR, IL, IT, RS, YU	G3, G4	White peach scale, *Pseudaulacaspis pentagona* (parasite)	Battaglia et al. (1994), Herting (1972), Kozarazhevskaya and Mihajlovic (1983), Mendel et al. (1984)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Aphelinus mali (Haldeman, 1851)	A	parasitic/ predator	North America	1921, IT	AL, AT, BG, CH, CZ, DE, DK, FR, HU, IL, IT, MD, NL, PT, RO, RU, SI, SK, UA,	I2	Woolly apple aphid, *Eriosoma lanigerum (*Monophagous parasitoid)	Del Guercio (1925)
Aphelinus semiflavus Howard, 1908	A	parasitic/ predator	North America	1953, ES	DE, ES, IL, IT	I,	Aphids (*Acyrtosiphon pisum, Macrosiphum*, etc.)	Herting (1972), Janssen (1961), Thompson (1953)
Aphytis abnormis (Howard, 1881)	A	parasitic/ predator	North America	1953, FR	ES, FR-COR, GR, HU	G4	Diaspidids and coccids scale insects (*Lepidosaphes, Coccus*)	Herting (1972), Peck (1963), Stathas and Kontodimas (2001), Thompson (1953)
Aphytis acrenulatus DeBach & Rosen, 1976	A	parasitic/ predator	Africa	1994, IT	IT	I	Diaspidid scale insects (*Aspidiella zingiberi* and *Rhizaspidiotus donacis*))	Garonna (1994)
Aphytis chilensis Howard, 1900	A	parasitic/ predator	South America	1910, ES	CY, DE, ES, FR, GR, IT-SIC	I, G3, J100	Diaspidid scale insects (*Aspidiotus, Hemiberlesia* etc.)	Alexandrakis and Neuenschwander (1979), Herting (1972), Liotta (1974), Mercet (1911), Thompson (1953), Viggiani (1994a)
Aphytis coheni DeBach, 1960	A	parasitic/ predator	Asia	1959, IL	CY, GR, IL	I	*Chrysomphalus dictyospermi* on *Citrus*	DeBach (1960), Rosen and DeBach (1979), Wood (1962)
Aphytis diaspidis (Howard, 1881)	A	parasitic/ predator	North America	1952, F	AT, CY, ES, FR, GR, IL, IT, NL, PL	I, G3	Diaspidid scale insects	Applebaum and Rosen (1964), Herting (1972), Rosen and DeBach (1979), Thompson (1953)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Aphytis holoxanthus DeBach, 1960	A	parasitic/ predator	Asia	1959, IL	BE, CY, CZ, DE, ES, FR, IL, NL	I, J100	Diaspidid scale insects (*Chrysomphalus ficus*), *Citrus*, *Ficus*, *Musa*, *Cucurbita*	DeBach (1960), Wood (1962)
Aphytis lepidosaphes Compere, 1955	A	parasitic/ predator	Asia	1961, CY	CY, ES, FR, FR-COR, GR, GR-CRE, IL, IT	I	*Lepidosaphes beckii* on *Citrus*	Argyriou (1974), Benassy et al. (1974), Rosen (1965), Rosen and DeBach (1979), Viggiani and Iannaconne (1972), Wood (1962)
Aphytis lingnanensis Compere, 1955	A	parasitic/ predator	Asia	1966, IT	AL, CY, ES, GR, IL, IT	I	*Aonidiella aurantii* and other scales on *Citrus*	Argov et al. (1995), Rosen and DeBach (1979), Viggiani (1994a)
Aphytis melinus DeBach, 1959	A	parasitic/ predator	Asia	1966, IT-SIC	AL, BE, CY, CZ, DE, DK, ES, FR, GR, IL, IT-SIC, IT, PT	I, J100	*Aonidiella aurantii* on *Citrus*	Alexandrakis and Benassy (1981), Inserra (1971), Rosen and DeBach (1979), Viggiani (1994a)
Aphytis mytilaspidis (Le Baron, 1870)	A	parasitic/ predator	North America	1837, FR	BE, BG, CH, CY, CZ, DE, ES, FR, GB, GR, HR, HU, IT, ME, NL, PL, RO, RS, SE, SI, SK, UA,	I, G3, J100	Diaspidid scale insects	Rosen and DeBach (1979), Viggiani (1994a)
Aphytis yanonensis DeBach &Rosen, 1982	A	parasitic/ predator	Asia	1986, FR	FR, GR	I, J100	Scale parasitoidon citrus	Benassy and Pinet (1987)
Cales noacki Howard, 1907	A	parasitic/ predator	C & S America	1970, IT	ES, ES-CAN, FR, GR, IL, IT, IT-SAR, IT-SIC, MT, PT	I, J100	*Aleurothrixus floccosus* on *Citrus*	Carrero (1979), Del Bene and Gargani (1991), Onillon (1973), Spicciarelli et al. (1996)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Centrodora speciosissima (Girault, 1911)	A	parasitic/ predator	North America	1943, HU	AT, DE, HU, RU, UA	I	Pupae of dipterous, chalcid and proctotrupids (hyperparasitoid)	Erdös (1953), Herting (1978), Peck (1963), Thompson (1953)
Coccobius fulvus (Compere & Annecke, 1961)	A	parasitic/ predator	North America	1986, FR	FR	I2, J100	Diaspidid scales on ornemental plants and *Citrus*	Benassy and Pinet (1987)
Coccophagoides murtfeldtae (Howard, 1894)	A	parasitic/ predator	North America	1962, IT	IT	I	*Pseudaulacaspis pentagona*	Peck (1963)
Coccophagoides utilis Doutt, 1966	A	parasitic/ predator	North America	1975, GR	GR	I	*Parlatoria oleae* on olive tree	Argyriou and Kourmadas (1979)
Coccophagus bivittatus Compere, 1931	A	parasitic/ predator	Africa	1960, IT	IL, IT	I	*Coccus hesperidum*	Herting (1972), Zinna (1961)
Coccophagus capensis Compere, 1931	A	parasitic/ predator	Africa	1962, IT-SIC	IL, IT-SIC	I	*Saissetia oleae*	Argov and Rössler (1988), Peck (1963)
Coccophagus ceroplastae (Howard, 1895)	A	parasitic/ predator	Asia	1975, FR	FR, IL	I, J100	*Saissetia oleae* and *Ceroplastes floridensis* on *Citrus*	Argov and Rössler (1988), CIBC (1976)
Coccophagus cowperi Girault, 1917	A	parasitic/ predator	Africa	1963, IT	GR, IL, IT	I	*Saissetia oleae* and other coccids, (sometimes hyperparasitoid)	Ben-Dov (1978)
Coccophagus flavoscutellum Ashmead, 1881	A	parasitic/ predator	North America	1962, IT-SIC	IT-SIC	I	*Coccus oleae*	Monastero (1962)
Coccophagus gossypariae Gahan, 1927	A	parasitic/ predator	North America	1990, IT	DE, IT	I	*Gossyparia spuria* (Eriococcidae)	Viggiani (1998), Viggiani (1999), Viggiani and Romagnoli (1995)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Coccophagus gurneyi Compere, 1929	A	parasitic/ predator	Asia	1973, IT	IT	I	*Pseudococcus fragilis*	Viggiani (1975a)
Coccophagus matsuyamensis Ishihara, 1977	A	parasitic/ predator	Asia	1979, IT	IT,	I	*Coccus hesperidum*	Viggiani (1980)
Coccophagus saissetiae (Annecke & Mynhardt,1979)	A	parasitic/ predator	Africa	1978, IL	IL, IT	I	*Saissetia oleae* on *Citrus*	Annecke and Mynhardt (1979b), Mazzone and Viggiani (1983)
Coccophagus scutellaris (Dalman, 1825)	C	parasitic/ predator	Crypto-genic	1826, SE	AL, BE, DE, ES, FR, IL, NL, PT, SE	I, J100	scales on *Citrus*, Vine, *Populus* and others (polyphagous)	Carrero (1980), Faber and Sengonca (1997), Montiel and Santaella (1995), Oncuer (1974), Panis et al. (1977), Paraskakis et al. (1980)
Coccophagus silvestrii Compere, 1931	A	parasitic/ predator	Asia-Temperate	1972, FR	CZ, FR,	I, J100	Various coccids on *Citrus*	Viggiani and Mazzone (1979)
Coccophagus varius (Silvestri, 1915)	A	parasitic/ predator	Africa	1983, IT	IL, IT	I	*Saissetia oleae*	Mazzone and Viggiani (1983)
Encarsia acaudaleyrodis Hayat, 1976	A	parasitic/ predator	Asia	1999, ES-CAN	ES-CAN	J100	Aleyrodidae	Hernández-Suárez et al. (2003)
Encarsia aurantii (Howard, 1894)	A	parasitic/ predator	North America	1941, IT	CH, DE, FR, HU, IT, PL	I, G3	Diaspidid scale insects (polyphagous)	Howard (1895)
Encarsia azimi Hayat, 1986	A	parasitic/ predator	Asia	2001, IT	ES, ES-CAN, IT,	I, J100	Aleyrodidae on various cultivated plants	Gonzalez Zamora et al. (1996), Kirk et al. (1993)
Encarsia berlesei (Howard, 1906)	A	parasitic/ predator	Asia	1906, IT	AL, AT, BG, CH, DE, ES, FR, GR, HR, HU, IT, IT-SAR, IT-SIC, ME, RU, SI, YU	I	*Pseudaulacaspis pentagona*	Ferrière (1961), Howard (1912), Silvestri (1908)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Encarsia citrina (Craw, 1891)	C	parasitic/ predator	Crypto- genic	1915, NL	BE, DE, ES, FR, NL	J100	Scals on olive, *Citrus*, etc (polyphagous)	Ghesquière (1933), Smits van Burgst (1915)
Encarsia diaspidicola (Silvestri, 1909)	A	parasitic/ predator	Asia	1962, IT	IT	I	*Pseudaulacaspis pentagona*	Peck (1963)
Encarsia fasciata (Malenotti, 1917)	C	parasitic/ predator	Crypto- genic	1917, IT	CH, DE, ES, FR, IL, IT	I	Scales on *Laurus*, *Citrus*, *Populus*, *Crataegus*, *Malus*	Gerson (1967), Herting (1972), Malenotti (1917), Neuffer (1962), Thompson (1953)
Encarsia formosa (Gahan, 1924)	A	parasitic/ predator	C & S America	1964, BU	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES-CAN, FI, FR, GB, HU, IE, IL, IT, IT-SAR, IT-SIC, IT, LT, MT, NL, NO, PL, PT, RO, RS, SE, SK	I, J100	Whiteflies	Burnett (1962), Gerling (1966), Kowalska (1969), Lenteren et al. (1976), Scopes (1969), Stenseth (1976), Viggiani (1987)
Encarsia guadeloupae Viggiani, 1987	A	parasitic/ predator	C & S America	2000, ES-CAN	ES-CAN	I	*Aleurodicus dispersus* and Lecanoideus floccissimus	Nijhor, 2000 #587}
Encarsia herndoni (Girault, 1935)	A	parasitic/ predator	Asia	1987, FR	AL, ES, FR-COR, IT, IT-SIC	I, J100	*Insulaspis gloverii*, scale on Citrus	Benassy and Brun (1989), Liotta et al. (2003), Maniglia et al. (1995), Viggiani (1987)
Encarsia hispida De Santis, 1948	A	parasitic/ predator	South America	1992, IT	ES-BAL, ES-CAN , FR, IT,	I, J100	*Bemisia*	Nijhof et al. (2000)
Encarsia inquirenda (Silvestri, 1930)	A	parasitic/ predator	Asia - Temperate	1979, ES	ES, IL, IT	I2	*Lepidospahes glovenii* on *Citrus*, against	Viggiani (1987)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Encarsia lahorensis (Howard, 1911)	A	parasitic/ predator	Asia	1973, IT	FR, GR, IL, IT, IT-SAR, IT-SIC, RU,	I, J100	Citrus whitefly, *Dialeurodes citri* (specific parasitoid)	Pappas and Viggiani (1979), Viggiani (1981), Viggiani and Mazzone (1977a), Viggiani and Mazzone (1978)
Encarsia lounsburyi (Berlese & Paoli, 1916)	A	parasitic/ predator	Africa	1922, IT	AL, CH, CY, ES, ES-BAL, FR, FR-COR, FR, GR, IL, IT, NL, PT	I, J100	*Insulaspis gloverii* scale on *Citrus*	Viggiani (1987)
Encarsia meritoria Gahan, 1927	A	parasitic/ predator	North America	1990, IT	IT, IT-SIC	I	*Bemisia tabaci* on *Gossypium*	Viggiani (1987)
Encarsia pergandiella Howard, 1907	A	parasitic/ predator	Asia?	1978, IT	FR, IL, IT, IT-SIC	I	*Bemisia*	Buijs et al. (1981), Rivnay and Gerling (1987), Viggiani (1987)
Encarsia perniciosi (Tower, 1913)	A	parasitic/ predator	Asia	1946, IT	AL, AT, BG, CH, CZ, DE, DK, YU, FR, GR, GL, IT, IT-SIC, RO, RS, SK, YU	I	San Jose scale	Bénassy et al. (1965), Bénassy et al. (1968), Gambaro (1965), Mathys and Guignard (1962), Neuffer (1962), Neuffer (1968)
Encarsia porteri (Mercet, 1928)	A	parasitic/ predator	South America	1993, IT	IT	I	Aleyrodidae and various insect eggs	Viggiani and Gerling (1994b)
Encarsia protransvena Viggiani, 1985	A	parasitic/ predator	North America	1998, ES	ES, IT	I	Aleyrodidae and scale insects	Giorgini (2001), Polaszek et al. (1999)
Encarsia sophia (Girault & Dodd,1915)	A	parasitic/ predator	Asia	1992, IT	ES, ES-CAN, IL, IT,	I	*Bemisia* and whiteflies	Gonzalez Zamora et al. (1996), Hernández-Suárez et al. (2003), Pedata and Viggiani (1993), Viggiani and Gerling (1994a)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Eretmocerus californicus Howard, 1895	A	parasitic/ predator	North America	1987, IL	DE, ES, IL, IT, MT, PL	I	*Bemisia*	Abd-Rabou (1999), Albert and Schneller (1994), Argov and Rössler (1988), Baraja et al. (1996), Bednarek and Goszczynski (2002), Mifsud (1997)
Eretmocerus corni Haldeman, 1850	A	parasitic/ predator	North America	1963, IT	GR, IT	I	*Siphoninus phillyreae* (Aleyrodidae)	Menteelos (1967)
Eretmocerus debachi Rose & Rosen, 1992	A	parasitic/ predator	North America	1991, IT	IL, IT, IT-SIC,	I	*Parabemisia myricae* on citrus	Rose and Rosen (1992)
Eretmocerus eremicus Rose & Zolnerowich, 1997	A	parasitic/ predator	North America	1994, CZ	BE, CH, CZ, DK, ES, FI, FR, DE, GR, HU, IT, LT, MT, NL, NO, PL, PT, SK	I, J100	*Bemisia, Trialeurodes*	Berndt et al. (2007), Gerling et al. (2001), Gonzalez et al. (2008), Lacordaire and Dussart (2008), Mary (2005), Rose and Zolnerowich (1997), Stansly et al. (2005)
Eretmocerus haldemani Howard, 1908	A	parasitic/ predator	Asia	1968, FR-COR	FR-COR, UA	I	Aleyrodids (*Bemisia, Trialeurodes*) on *Citrus, Solanum*, ..	Chumak (2003), Onillon (1969)
Eretmocerus paulistus Hempel, 1904	A	parasitic/ predator	North America	1970, ES	AL, ES	I	*Aleurothrixus floccosus* in *Citrus* groves	DeBach and Rose (1976a), DeBach and Rose (1976b)
Marietta carnesi (Howard, 1910)	A	parasitic/ predator	Asia	1987, ES	IT, ES	I	Hyperparasitoid	Rosen (1962)
Pteroptrix chinensis (Howard, 1907)	A	parasitic/ predator	Asia	1974, IT	IT, RU	I	*Mytilococcus beckii* on *Citrus*	Liao et al. (1987), Viggiani (1975a)
Pteroptrix orientalis (Silvestri, 1909)	A	parasitic/ predator	Asia	1909, IT	IT	I	*Chrysomphalus dictyospermi*	Viggiani and Garonna (1993)
Pteroptrix smithi (Compere 1953)	A	parasitic/ predator	Asia	1968, IL	IL, IT	I	*Chrysomphalus aonidum*	Flanders (1969), Viggiani (1975a)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Bethylidae								
Cephalonomia waterstoni Gahan, 1931	C	parasitic/ predator	Crypto-genic	Unknown, GB	GB	J	Grain beetles (*Cryptolestes*)	Finlayson (1950)
Holepyris sylvanidis (Brèthes, 1913)	C	parasitic/ predator	Crypto-genic	Unknown, GB	GB	J	*Tribolium confusum* (Larval parasitoid)	Fitton et al. (1978)
Laelius utilis Cockerell, 1920	A	parasitic/ predator	North America	Unknown, SE	SE	J	*Anthrenus*	Gordh and Moczar (1990)
Plastanoxus laevis (Ashmead, 1893)	A	parasitic/ predator	North America	Unknown	ES, FR, IL, IT	J	Various grain beetles (Cucujidae)	Tussac and Blasco-Zumeta (1999)
Braconidae								
Aphidius colemani Viereck, 1912	A	parasitic/ predator	Asia-Temperate	1965, CZ	AL, AT, BE, CH, CZ, DE, DK, ES, FI, , FR, FR-COR, GB, GR, HU, IE, IT, LT, MT, NL, NO, PL, PT, PT-MAD, SE, SK,	E, I1, I2, J100	Aphids in greenhouses	Clausen (1978), Stary (1975), Stary and Remaudiere (1973), Stary et al. (1977){
Aphidius smithi Sharma & Subba Rao, 1959	A	parasitic/ predator	Asia-Temperate	1960, PL	AL, BG, CH, CY, CZ, DE, DK, ES, ES-CAN, FI, GR, HR, HU, IE, IL, IT, IT-SIC, LT, MD, NL, PL, PT, PT-MAD, RU, SK, UA	I	*Acyrthosiphon kondoi* and *A. pisum*	Pennacchio (1989)
Cotesia hyphantriae (Riley, 1887)	A	parasitic/ predator	North America	1953, YU	YU	G4	*Hyphantria cunea*	Glavendekic (2000)
Cotesia marginiventris (Cresson,1865)	A	parasitic/ predator	North America	1993, FR	BE, DE, ES, FR, NL	J100	grasslands (N)-greenhouses (I)	Clausen (1978)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Diachasmimorpha fullawayi (Silvestri, 1912)	A	parasitic/ predator	Africa	Unknown, IT	IT	I	fruit-Infesting Tephritidae	Clausen (1978)
Diachasmimorpha tryoni (Cameron, 1911)	A	parasitic/ predator	Australasia	1932, ES	ES, ES-CAN, IL	I	fruit-Infesting Tephritidae	Clausen (1978)
Heterospilus cephi Rohwer, 1925	A	parasitic/ predator	North America	Unknown, GB	GB	I	*Cephus pygmeus*	Clausen (1978)
Hymenochaonia delicata (Cresson 1872)	A	parasitic/ predator	North America	1933, FR	FR, IT	I	*Cydia molesta*	van Achterberg (1993)
Lysiphlebus testaceipes (Cresson, 1880)	C	parasitic/ predator	Crypto-genic	1965, CZ	AL, BG, CZ, DK, ES, FR FR-COR, IT, IT-SIC, PT	E, I	Aphids	Barbagallo et al. (1983), Costa and Stary (1988), Kavallieratos and Lykouressis (1999), Ortu and Prota (1983), Stary et al. (1985), Steenis (1992), Tremblay et al. (1978)
Macrocentrus ancylivorus (Rohwer, 1923)	A	parasitic/ predator	North America	1930, IT-SAR	FR-COR, IT-SAR,	i	*Ancylis comptana*	Labeyrie (1957)
Microgaster pantographae Muesebeck, 1922	A	parasitic/ predator	North America	Unknown, GB	GB	I	Tortricid moths	Fitton et al. (1978)
Opius dimidiatus Ashmead, 1889	A	parasitic/ predator	North America	Unknown, NL	NL	I1	*Liriomyza trifolii (*Solitary endoparasitoid)	van der Linden (1986)
Pauesia cedrobii Starý & Leclant 1977	A	parasitic/ predator	Africa	1987, FR	FR, IL	G1, I2	*Cedrodium* on *Cedrus*	Fabre and Rabasse (1987), Remaudière and Stary (1993)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Pauesia unilachni (Gahan, 1927)	A	parasitic/ predator	Asia	1930, ES	ES, IT	G3	Grey pine aphid, *Schizolachnus pineti*	Quilis Pérez (1931)
Perilitus vittatae (Muesebeck, 1936)	A	parasitic/ predator	North America	Unknown, DE	DE	I	*Phyllotreta* leaf beetles (adults)	Haeselbarth (2008)
Psyttalia concolor (Szépligeti, 1910)	A	parasitic/ predator	Africa	1914, IT	FR, GL, IT	G4	Fruit-Infesting Tephritidae	Clausen (1978), Delanoue (1960)
Ceraphronidae								
Aphanogmus bicolor Ashmead, 1893	A	parasitic/ predator	North America	Unknown	AT, BE, CH, DK, FI, GR, HR, RS	I	Cecidomyidae	Dessart (1994)
Chalcididae								
Dirhinus giffardii Silvestri,1913	A	parasitic/ predator	Africa	1912, IT	GR, IL, IT	I	Fruits	Greathead (1976), Podoler and Mazor (1981), Thompson (1953)
Cynipidae								
Dryocosmus kuriphilus Yasumatsu, 1951	A	phyto-phagous	Asia-Temperate	2002, IT	CH, FR, HU, IT, SI	G1, I2	*Castanea*	Anonymous (2005), Breisch and Streito (2004), Csoka et al. (2009), Forster et al. (2009), Graziosi and Santi (2008)
Dryinidae								
Neodryinus typhlocybae (Ashmead, 1893)	A	parasitic/ predator	North America	1994, IT	CH, FR, IT, SI	I	*Metcalfa pruinosa*	Malausa (1999), Malausa et al. (2003)
Encyrtidae								
Adelencyrtus aulacaspidis (Brèthes, 1914)	A	parasitic/ predator	South America	1930, FR	BG, CH, CZ, DE, ES, FR, GB, HR, HU, IT, RU, SI, UA	G3, G4	Various Diaspididae	Trjapitzin (1989)
Aenasius flandersi Kerrich, 1967	A	parasitic/ predator	South America	1999, ES-CAN	ES-CAN	I	*Phenacoccus manihoti*	Baez and Askew (1999)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ageniaspis citricola Logvinovskaya, 1983	A	parasitic/ predator	Asia?	1966, IT-SIC	FR, ES, ES-CAN, GR, IL, IT, IT-SIC, PL	I, J100	Citrus leafminer, *Phyllocnistis citrella*, in *Citrus* orchards	Argov and Rössler (1996), Michelakis (1997), Siscaro et al. (1997), Siscaro and Mazzeo (1997), Urbaneja et al. (2000)
Aloencyrtus saissetiae (Compere,1939)	A	parasitic/ predator	Africa	1987, IL	IL	I	*Saissetia oleae* on citrus.	Argov and Rössler (1988)
Anagyrus agraensis Saraswat,1975	A	parasitic/ predator	Asia	1987, IL	IL	I	*Nipaecoccus viridis*	Bar-Zakay et al. (1987)
Anagyrus fusciventris (Girault, 1915)	A	parasitic/ predator	Australasia	1983, IT	BE, DE, DK, ES, FR, DE, IT, NL	J100	pseudococcids on Cycas, coffee, *Citrus*	Viggiani and Battaglia (1983)
Anagyrus sawadai Ishii,1928	A	parasitic/ predator	Asia	1996, IL	IL	I	*Citrus* mealybug, *Pseudococcus cryptus*	Blumberg et al. (1999b)
Anagyrus subflaviceps (Girault, 1915)	A	parasitic/ predator	Australasia	1994, PT	ES, IL, PT	I	Pseudococcids	Simutnik et al. (2005)
Anicetus annulatus Timberlake, 1919	A	parasitic/ predator	North America	1977, HR	AL, HR	I	Scale insects on *Citrus*	Hoffer (1970), Hoffer (1982)
Anicetus ceroplastis Ishii,1928	A	parasitic/ predator	Asia	1989, IL	IL	I	*Ceroplastes floridensis*	Blumberg (1977)
Anthemus hilli Dodd, 1917	A	parasitic/ predator	Australasia	1954, ES	ES	I	*Chionaspis graminis*	Gerling et al. (1980)
Avetianella longoi Siscaro, 1992	A	parasitic/ predator	Australasia	1990, PT	IT-SIC, IT, PT	I, G1	*Phoracantha semipunctata (*Oophagous)	Farrall et al. (1992), Longo et al. (1993), Siscaro (1992)
Bothriophryne fuscicornis Compere, 1939	A	parasitic/ predator	Africa	1972, IL	CZ, IL, SK	I, G	Various Coccidae	Kfir and Rosen (1980)
Clausenia purpurea Ishii,1923	A	parasitic/ predator	Asia	1974, IL	IL, IT	I	Citriculus mealybug *Pseudococcus cryptus*	Guerrieri and Pellizzari (2009), Rosen (1974)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Coccidencyrtus malloi Blanchard, 1964	A	parasitic/ predator	South America	1999, FR	FR, IT	J100	*Diaspis boisduvalii*	Panis and Pinet (1999a)
Coccidoxenoides perminutus Girault, 1915	A	parasitic/ predator	Asia	1956, IT	CY, GB, IL, IT	I, J100	*Planococcus ficus* and *P. citri*	Fry (1989), Noyes and Hayat (1994), Trjapitzin (1978), Viggiani (1975a), Zinna (1960)
Comperia merceti (Compere, 1938)	A	parasitic/ predator	South America	1988, FR	F, IT	J	*Supella longipalpa*	Goudey-Perrière et al. (1988), Goudey-Perrière et al. (1991)
Comperiella bifasciata Howard, 1906	A	parasitic/ predator	Asia	1990, IT	BE, CY, CZ, ES, FR, GR, HU, IL, IT, IT-SIC, MD, NL, RU, UA	I, J100	*Aonidiella aurantii* & *A. citrina* on Citrus & passionfruit	Bénassy and Bianchi (1974), Liotta and Salvia (1991), Orphanides (1996)
Comperiella lemniscata Compere & Annecke, 1961	A	parasitic/ predator	Asia	1989, IT	ES, IL, IT	I	*Chrysomphalus dictyospermi*	Battaglia (1988), Garonna and Viggiani (1989), Pina et al. (2001)
Copidosoma floridanum (Ashmead, 1900)	A	parasitic/ predator	North America	1920, GB	BG, CZ, DE, ES, ES-CAN, FR, DE, GB, GR-CRE, HU, IT, NL, PT, RU, RS, SE, SK	I	Noctuid moths (Polyembryonic)	Guerrieri and Noyes (2005), Noyes (1988)
Copidosoma koehleri Blanchard, 1940	A	parasitic/ predator	C & S America	1994, IT	AL, CY, GR, IT	I	*Phtorimea operculella*	Guerrieri (1995), Guerrieri and Noyes (2005)
Diversinervus cervantesi (Girault,1933)	A	parasitic/ predator	Asia	1982, IL	IL	I	soft scale insects	Rosen and Alon (1983)
Diversinervus elegans Silvestri, 1915	A	parasitic/ predator	Africa	1977, IT	ES, FR, GR, IL, IT	I	black scale, *Saissetia oleae,* on olive, Citrus (polyphagous)	Kfir and Rosen (1980), Panis (1983), Viggiani and Mazzone (1977b)
Encyrtus fuscus (Howard, 1881)	A	parasitic/ predator	North America	1901, IT	IT	I, G3	*Lecanium* scales	Noyes and Hayat (1994)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Encyrtus infelix (Embleton, 1902)	A	parasitic/ predator	Africa	1901, GB	BE, DE, DK, ES, FR, GB, IL, NL	I, J100	Coccids (*Saissetia* spp.) on Citrus, Ficus	Embleton (1902)
Leptomastix dactylopii Howard, 1885	A	parasitic/ predator	Africa	1959, IT	AT, BA, BE, CY, CZ, DE, DK, ES, FI, FR, DE, GB, GR, IE, IL, IT, IT-SAR, IT-SIC, NL, NO, PL, PT, SE, YU	I, J100	Mealybugs (*Planococcus citri*) on many host plants (polyphagous)	Krambias and Kotzionis (1980), Longo and Benfatto (1982), Luppino (1979), Mineo and Viggiani (1976), Viggiani (1975b)
Metaphycus angustifrons Compere,1957	A	parasitic/ predator	Asia	1988, IL	IL	I2	Coccids on Nerium oleander, Asteraceae, *Cupressus* spp.., *Leonotis leoneurus*, *Olea* europaea, *Leucadendron pubescens*, Lycium tetrandrum	Trjapitzin (1989)
Metaphycus anneckei Guerrieri & Noyes, 2000	A	parasitic/ predator	Africa	1973	CY, ES, GR, IL, IT, PL, PT	I2	Coccids on *Nerium oleande*r, Asteraceae, *Cupressus* spp., *Leonotis leoneurus, Olea europaea, Leucadendron pubescens, Lycium tetrandrum*	Guerrieri and Noyes (2000)
Metaphycus flavus (Howard, 1881)	A	parasitic/ predator	North America	1915, FR	AL, CY, CZ, FR, ME, PT-MAD, PT, RU, ES-BAL	I	soft scales (Facultative gregarious parasitoid)	Monaco and D'Abbicco (1987), Noguera et al. (2003), Orphanides (1988), Tena-Barreda and Garcia-Mari (2006), Velimirovic (1994)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Metaphycus galbus Annecke, 1964	A	parasitic/ predator	Africa	1993, ES	ES	I	*Protopulvinaria pyriformis* on avocado	Guerrieri and Noyes (2000)
Metaphycus helvolus (Compere, 1926)	A	parasitic/ predator	Africa	1978, IT	AT, BE, CH, CY, DE, DK, ES, FR, FR-COR, GR, IL, IT, NL, SE	J100	Scale insects. Only in greenhouses	Argyriou and Katsoyannos (1976), Carrero (1980), Mazzone and Viggiani (1983), Montiel and Santaella (1995), Panis (1983), Panis et al. (1977), Stratopoulou and Kapatos (1984), Viggiani (1978)
Metaphycus inviscus Compere,1940	A	parasitic/ predator	Africa	1987, IT-SAR	ES, ES-BAL, IL	I2	Black scale, *Saissetia*	Argov and Rössler (1988), Guerrieri and Noyes (2000)
Metaphycus lounsburyi (Howard, 1898)	A	parasitic/ predator	Africa	1973, IT	CY, DK, ES, FR, IL, IT, IT-SIC, NL, PL	I2, J100	Black scale, *Saissetia oleae*, polyphagous on olive, citrus	Argyriou and Michelakis (1975), Canard and Laudeho (1977), Monaco (1976), Monaco and D'Abbicco (1987), Orphanides (1988), Panis (1977), Panis and Marro (1978), Tena-Barreda and Garcia-Mari (2006)
Metaphycus luteolus (Timberlake, 1916)	A	parasitic/ predator	North America	1989, IT	ES, IT, UA	I2	Fruit scales	Guerrieri and Noyes (2000), Viggiani and Guerrieri (1988)
Metaphycus maculipennis (Timberlake, 1916)	A	parasitic/ predator	North America	1988, IT	DE, ES, FR, GR, IT, RS		Coccidae on *Vitis*	Guerrieri and Noyes (2000)
Metaphycus orientalis (Compere, 1924)	A	parasitic/ predator	Asia	1989, BE	BE	I	Coccidae on *Citrus*	Guerrieri and Noyes (2000)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Metaphycus stanleyi Compere, 1940	A	parasitic/ predator	Africa	1960, IT	ES-CAN, ES, GR, IL, IT	I2	fruit scales	Argov and Rössler (1988), Blumberg et al. (1993), Guerrieri and Noyes (2000), Noyes and Hayat (1994), Trjapitzin (1989)
Metaphycus swirskii Annecke & Mynhardt, 1979	A	parasitic/ predator	Africa	1976, IT	ES , FR, GR, GR-CRE, IL, IT, NL	I2	scales on *Ficus, Citrus*, Coffee, *Solanum*	Annecke and Mynhardt (1979a), Panis (1981), Viggiani and Mazzone (1977b)
Microterys clauseni Compere,1926	A	parasitic/ predator	Asia	1987, IL	IL	I	*Ceroplastes floridensis* on *Citrus*	Argov and Rössler (1988)
Microterys nietneri (Motschulsky, 1859)	A	parasitic/ predator	Asia	1989, BG	BG, PT-AZO	I2	*Coccus*	Simoes et al. (2006)
Microterys speciosus Ishii,1923	A	parasitic/ predator	Asia	1987, IL	IL	I	*Ceroplastes floridensis* on Citrus	Argov and Rössler (1988)
Neodusmetia sangwani (Subba Rao,1957)	A	parasitic/ predator	Asia	1974, IL	IL	E	Rhodesgrass scale, *Antonina graminis*	Gerson et al. (1975)
Ooencyrtus kuwanae (Howard, 1910)	A	parasitic/ predator	Asia Temperate	1932, PT	AT, BA, BG, CH, CZ, DE, ES, FR, IT-SAR, MD, PL, PT, RO, RU, SK, UA, YU	G1	*Lymantria dispar*	Bjegovic (1962), Keremidchiev et al. (1980), Mihalache et al. (1995), Milanovic et al. (1998), Roversi et al. (1991)
Plagiomerus diaspidis Crawford, 1910	A	parasitic/ predator	North America	1994, IT-SIC	ES-CAN, FR, IT-SIC, PT-MAD	I	Diaspididae on *Opuntia*	Bue and Colazza (2005), Panis and Pinet (1999b), Russo and Siscaro (1994)
Prochiloneurus pulchellus Silvestri, 1915	A	parasitic/ predator	Africa	1972, IL	IL, IT	I	scale insects (polyphagous)	Trjapitzin (1989)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Pseudaphycus angelicus (Howard, 1898)	A	parasitic/ predator	Tropical, subtropical	1964, IL	IL, RU	I, J100	Pseudococcids (*Vitis*, *Solanum*)	Noyes and Hayat (1994), Walton and Pringle (2002)
Pseudaphycus malinus Gahan,1946	A	parasitic/ predator	Asia-Temperate	1998, IL	IL, RU	I, J100	Pseudococcids on *Citrus*	Blumberg et al. (1999a)
Pseudectroma signatum (Prinsloo,1982)	A	parasitic/ predator	Africa	1986, IL	IL	I2	*Nipaecoccus viridis* on *Citrus*	Bar-Zakay et al. (1987)
Psyllaephagus pilosus Noyes, 1988	A	parasitic/ predator	Australasia	2006, FR-COR	FR, FR-COR, GB, IE, IT	I2	*Ctenarytaina eucalypti* on *Eucalyptus*	Bennett (2005), Chauzat et al. (2002), Costanzi et al. (2003a), Costanzi et al. (2003b), Malausa and Girardet (1997), Schnee et al. (2006)
Rhopus nigroclavatus (Ashmead, 1902)	A	parasitic/ predator	North America	1978, ES	ES	I	scale insects on Poaceae	Trjapitzin (1989)
Tachinaephagus zealandicus Ashmead, 1904	A	parasitic/ predator	Australasia	2002, PT-MAD	DK, IT, PT-AZO, PT-MAD	J	*Musca domestica* in poultry houses	Japoshvili and Noyes (2006), Koponen and Askew (2002), Turchetto et al. (2003)
Tetracnemoidea brevicornis (Girault, 1915)	A	parasitic/ predator	Australasia	1987, IT	FR, IT	I, J100	citrus mealybug, Pseud*ococcus calceolariae*	Laudonia and Viggiani (1986a)
Tetranecmoidea peregrina (Compere, 1939)	A	parasitic/ predator	C & S America	1994, PT	ES, FR, IL, IT, PT	I, J100	citrus mealybug, *Pseudococcus calceolariae*	Trjapitzin (1989)
Tineophoctonus armatus (Ashmead, 1888)	A	parasitic/ predator	North America	1963, ES	ES, IT	J	Anobiidae	Trjapitzin (1989)
Zarhopalus sheldoni Ashmead, 1900	A	parasitic/ predator	North America	1945, RU	RU	J100	*Pseudococcus comstocki*	Noyes and Hayat (1994)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Eulophidae								
Aceratoneuromyia indica (Silvestri, 1910)	A	parasitic/ predator	Australasia	1974, IT	GB, IT	I, J100	fruit flies, *Anastrepha*	Graham (1991), Viggiani (1975a)
Aprostocetus ceroplastae (Girault, 1916)	A	parasitic/ predator	Africa	1962, IL	FR, GR, IL, IT	I	Coccidae (Ceroplastes) on fruit trees	Argyriou and Kourmadas (1980), Avidov et al. (1963), Domenichini et al. (1964)
Aprostocetus diplosidis Crawford, 1907	A	parasitic/ predator	North America	1964, IT	IT	E	*Contarinia sorghicola*	Priore and Viggiani (1965)
Aprostocetus microcosmus (Girault, 1917)	A	parasitic/ predator	North America	1977, ES-CAN	ES-CAN	I	Cecidomyiidae on Poaceae	Graham (1987)
Aprostocetus sicarius (Silvestri, 1915)	A	parasitic/ predator	Africa	1962, IL	IL, ME	I	*Bactrocera oleae*	Avidov et al. (1963), OILB (1971)
Astichus trifasciatipennis (Girault, 1913)	A	parasitic/ predator	Australasia	1989, IT	IT	G5	Gracillariidae on *Robinia pseudoacacia*	Serini (1990)
Ceranisus americensis (Girault, 1917)	A	parasitic/ predator	North America	1994, NL	NL	I	Thrips	Loomans et al. (1995)
Ceranisus russelli (Crawford, 1911)	A	parasitic/ predator	North America	1954, GB	GB	I	Thrips	Thompson (1955)
Chaenotetrastichus semiflavus (Girault, 1917)	A	parasitic/ predator	North America	1995, DE	DE	G	Pompilidae	Vidal (1996)
Chouioia cunea Yang, 1989	A	parasitic/ predator	Asia	1990, IT	IT	G1	*Hyphantria cunea*	Boriani (1991)
Chrysocharis ainsliei Crawford, 1912	A	parasitic/ predator	North America	1984, IT	DK, IT	I	*Phytomyza* on artichokes	Hansson (1985), Ikeda (1996)
Chrysocharis oscinidis Ashmead, 1888	A	parasitic/ predator	North America	1984, NL	FR, NL	I	*Liriomyza*	Fry (1989), Woets and Linden (1985)

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Cirrospilus ingenuus Gahan,1932	A	parasitic/ predator	Asia	1994, IL	CY, ES, IL, PT-MAD, PT	I	*Phyllocnistis citrella* in *Citrus* orchards	Argov and Rössler (1996), Vercher et al. (2000)P
Citrostichus phyllocnistoides (Narayanan, 1960)	A	parasitic/ predator	Asia	1995, IL	ES-BAL, GR, IL, IT, IT-SIC, IT, PT	I	*Phyllocnistis citrella* in *Citrus* orchards	Argov and Rössler (1996), Barbagallo et al. (2000), Michelakis and Vacante (1997), Vercher et al. (2000)
Closterocerus cinctipennis Ashmead, 1888	A	parasitic/ predator	North America	1971, IT	IT	G5	*Parectopa robiniella* on *Robinia*	Vidano and Marletto (1972)
Diglyphus begini (Ashmead, 1904)	A	parasitic/ predator	North America	1988, CZ	CZ, NO	I	Leafminer parasitoid	Hagvar et al. (1994), Kalina (1989)
Edovum puttleri Grissell, 1981	A	parasitic/ predator	C & S America	1985, IT	IT, RU	I1	Colorado potato beetle	Laudonia and Viggiani (1986b), Yefremova (2002)
Elachertus cidariae (Ashmead, 1898)	A	parasitic/ predator	North America	1962, YU	YU	G1	fall webworm in deciduous trees	Tadic MD (1964)
Euderus cavasolae (Silvestri, 1914)	A	parasitic/ predator	Africa	1954, IT	IT	I	*Bactrocera oleae*	Thompson (1955)
Galeopsomyia fausta LaSalle, 1997	A	parasitic/ predator	C & S America	1999, ES	ES	I2	*Phyllocnistis citrella* on *Citrus*	Vercher et al. (2000)
Goetheana shakespearei Girault, 1920	A	parasitic/ predator	Australasia	1992, ES	ES	I	Thrips	Viggiani and Nieves Aldrey (1993)
Hyssopus thymus Girault, 1916	A	parasitic/ predator	North America	1970, DE	DE	G3, I2	*Rhyacionia buoliana* pine stands	Konig and Bogenschutz (1971)
Leptocybe invasa Fisher & LaSalle, 2004	A	phyto-phagous	Australasia	2003, PT	ES, FR, FR-COR, IL, IT, PT	G1	gall-former on *Eucalyptus*	Anagnou-Veroniki et al. (2008), Kim et al. (2008), Mendel et al. (2004), Protasov et al. (2008)

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Ophelimus maskelli (Ashmead 1900)	A	phyto-phagous	Australasia	2000, IT	ES, FR, FR-COR, GR, IL, IT, PT	G1	gall-former on *Eucalyptus camaldulensis* (N), other *Eucalyptus* (I)	Branco et al. (2009), Protasov et al. (2007a), Protasov et al. (2007b), Rizzo et al. (2006), Sasso et al. (2008)
Pediobius phyllotretae (Riley, 1884)	A	parasitic/ predator	North America	1944, CZ	CZ, DE, GB	I	*Phyllotreta zimmermanni*	Boucek (1965)
Quadrastichodella nova Girault, 1922	A	phyto-phagous	Australasia	1968, IL	ES, FR-COR, IL, IT, IT-SAR, PT	G1	gall-former on *Eucalyptus*	Boucek (1977a), Rasplus (1992)
Semielacher petiolata (Girault, 1915)	A	parasitic/ predator	Australasia	1995, IL	CY, ES, ES-BAL, GR, IL, IT, IT-SIC, PT	I2	*Phyllocnistis citrella* on *Citrus*	Argov and Rössler (1996), Barbagallo et al. (2000), Michelakis and Vacante (1997), Siscaro et al. (1999)
Tetrastichomyia clisiocampae (Ashmead, 1894)	A	parasitic/ predator	North America	1966, IT	IT	G1, I	Lepidoptera	Domenichini (1967)
Thripobius javae (Girault, 1917)	A	parasitic/ predator	Asia	1995, IT	BE, DE, DK, FR, IL, IT, IT-SIC, NL	J100	Greenhouse thrips on *Citrus, Viburnumn, Vitis* and others	Viggiani and Bernardo (1996), Wysoki et al. (2000)
Eupelmidae								
Anastatus japonicus Ashmead, 1904	A	parasitic/ predator	Asia	1920, HU	CZ, HU, SK, YU	G1	*Lymantria* and forest moths	Ruschka (1921)
Anastatus tenuipes Bolivar & Pieltain, 1925	A	parasitic/ predator	Africa	1999, IT	IT	J	*Supella longipalpa* (Blattidae)	Russo et al. (2000)
Eupelmus afer Silvestri, 1914	A	parasitic/ predator	Africa	1974, IT	IT	I	*Bactrocera oleae*	Viggiani (1975a)

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Eupelmus australiensis (Girault, 1913)	A	parasitic/ predator	Australasia	1964, IT	IT, SK, UA, YU	I, I1, F5	sorghum midge (Cecidomyiidae) and other midge on Poaceae	Boucek (1977b), Kalina (1989), Priore and Viggiani (1965), Trjapitzin (1978)
Eupelmus longicorpus Girault, 1915	A	parasitic/ predator	Australasia	1987, ES	ES	I	midge on Poaceae	Bouček (1988)
Eurytomidae								
Bruchophagus sophorae Crosby & Crosby, 1929	A	phyto-phagous	Asia	1960, RO	BG, HU, RO, RS, RU, SK, UA, YU	I2	*Sophora* seeds	Grubik (1992), Mihajlovic (1983), 3871996477
Eurytoma aloineae (Burks, 1958)	A	phyto-phagous	Africa	1957, DE	DE	J100	*Aloe*	Burks (1958)
Eurytoma orchidearum (Westwood, 1869)	A	phyto-phagous	North America	1962, FR	DK, FR, NL	J100	*Cattleya* and other orchids	Gijswijt (2003), Peck (1963)P
Prodecatoma cooki (Howard, 1896)	A	phyto-phagous	North America	1886, AT	AT	I	Grape wasp, *Vitis*	Howard (1896)
Tetramesa albomaculatum (Ashmead, 1894)	A	phyto-phagous	North America	1977, GB	BG, DE, GB, SE	I1	Wheat and Poaceae	Boucek and Graham (1978), Hedqvist (2003), Stojanova (2004), Vidal (2001)
Tetramesa maderae (Walker, 1849)	A	phyto-phagous	North America	1870, IT	ES, HU, IL, IT, RO, RU, UA	I1	wheat and Poaceae	Popescu (2004), Porchinsky (1881), Walker (1871)
Tetramesa swezeyi (Phillips & Poos, 1922)	A	phyto-phagous	Unknown	1977, RU	RU, UA	I1	wheat and Poaceae	Zerova (1978)
Figitidae								
Aganaspis daci (Weld, 1951)	A	parasitic/ predator	Africa	1970, FR	FR, GR_NEG	I	*Bactrocera oleae*	Nunez-Bueno (1982), Papadopoulos and Katsoyannos (2003)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Formicidae								
Brachymyrmex heeri Forel, 1874	A	parasitic/ predator	C & S America	1874, CH	CH, DE, FR, UA	J100	Greenhouses	Forel (1874)
Cardiocondyla emeryi Forel, 1881	A	parasitic/ predator	Africa	1894, PT	ES-CAN, PT-MAD	G, I2, J1, X24	Natural sites and gardens, arid sites	Heinze and Trenkle (1997), Kluger (1983), Reyes-Lopez et al. (2008), Wetterer et al. (2007)
Cardiocondyla mauritanica Forel, 1890	A	parasitic/ predator	Africa	1981, ES-CAN	CY, ES, ES-CAN, IL, IT, IT-SAR, IT-SIC PT-MAD	I2, X24, J1	Gardens, houses, buildings	Finzi (1936), Mei (1995), Wetterer et al. (2007)
Cardiocondyla obscurior (Wheeler, 1929)	A	parasitic/ predator	Africa	1930, IL	ES-CAN, IL	I2	Miscelleanous habitats, disturbed areas, beaches	Seifert (2003)
Cardiocondyla wroughtoni (Forel, 1890)	A	parasitic/ predator	Asia	1982, IL	IL	H5, J	Miscelleanous habitats, disturbed areas	Kluger (1983)
Crematogaster brevispinosa Mayr, 1870	A	parasitic/ predator	C & S America	1935, CZ	CZ	J100	Greenhouses	Šefrová and Laštůvka (2005)
Hypoponera ergatandria (Forel, 1893)	A	parasitic/ predator	C & S America	1952, DE	DE, FR	J	Sparse or no vegetation, buildings	Geiter et al. (2002)
Hypoponera punctatissima (Roger, 1859)	A	parasitic/ predator	Tropical, subtropical	1847, PT	AT, BE, BG, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, IE, IS, IT, LU, MT, NL, NO, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SK, UA, YU	J, J100, I2, X24	Antropophilic, in greenhouses or other heated biuldings, gardens in Madeira	Blacker (2007), Boer et al. (2003), Boer et al. (2006), Carniel and Governatori (1994), Czechowska and Czechowski (1999b), Dessart and Cammaerts (1995), Jones (1997), Seifert (1982), Wetterer et al. (2007)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Lasius neglectus Van Loon, Boomsma & Andrasfalvy, 1990	A	parasitic/ predator	Asia-Temperate	1973, HU	BE, BG, CZ, DE, ES, FR, GL, HU, PL, PT	I2, X24	Polygynous species, parks and gardens	Boomsma et al. (1990), Czechowska and Czechowski (1999a), Czechowska and Czechowski (2003), Dekoninck et al. (2002), Espadaler (1999), Markó (1988), Neumeyer (2008), Schultz and Busch (2009), Seifert (1992), Seifert (2000), Van Loon et al. (1990)
Lasius turcicus Sanctchi, 1921	A	parasitic/ predator	Asia-Temperate	1970, HU	AL, BE, BG, CZ, DE, DK, EE, ES, ES-CAN, FR, GR, HU, IT, PL, RO	I2, X24	Gardens	Seifert (1996)
Linepithema humile (Mayer, 1868)	A	parasitic/ predator	C & S America	1847, PT	BE, BG, CH, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, IT, IT-SAR, IT-SIC, PL, PT, PT-AZO, PT-MAD	J, G, I2	Various habitats indoors and outdoors	Giraud et al. (2002), Suarez et al. (2001), Wild (2004), Wild (2009)
Linepithema leucomelas Emery, 1894	A	parasitic/ predator	C & S America	1955, AT	AT	J100	Gardens, greenhouses	Wild (2007)
Monomorium andrei Saunders, 1890	A	parasitic/ predator	Africa	1924, ES	ES, ES-BAL	J	Urban environment	Reyes Lopez and Luqque Garcia (2003)
Monomorium destructor (Jerdon, 1851)	A	parasitic/ predator	Asia	1892, ES-BAL	ES-BAL, PL, PT	J1	Urban environment	Boer and Vierbergen (2008), Salgueiro (2003), Šefrová and Laštůvka (2005), Wetterer (2009a), Yarrow (1967)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Monomorium floricola (Jerdon, 1851)	A	parasitic/ predator	Asia-Tropical	1982, DE	DE	J100	Greenhouses	Sellenschlo (1991)
Monomorium pharaonis (Linnaeus, 1758)	A	parasitic/ predator	tropical	1892, ES	AT, BG, CH, CZ, DE, DK, EE, ES-CAN, FR, FR-COR, GB, HU, IL, IT, IT-SAR, IT-SIC, LT, ME, NL, NO, PT-MAD, PT, RS	J1, J100, X25, I2	Stored products antropophilic, mainly indoors, gardens in Madeira	Markó et al. (2006), Salgueiro (2003)
Monomorium salomonis (Linnaeus, 1758)	A	parasitic/ predator	tropical	1881, FRL	ES, ES-BAL, FR, GB, IT, IT-SAR, IT-SIC, MT	F6, J100	Garrigue	Salgueiro (2003)
Pachycondyla darwinii Forel, 1893	A	parasitic/ predator	Unknown	Unknown, MT	MT	U	Forested areas	
Paratrechina bourbonica (Forel, 1886)	A	parasitic/ predator	Tropical, subtropical	Unknown, GB	GB	U	Cosmopolitan, tropics	Fitton et al. (1978)
Paratrechina flavipes (Smith, 1874)	A	parasitic/ predator	Asia-Tropical	1952, DE	DE, ES	J1	Buildings	Espadaler and Colllingwood (2000)
Paratrechina jaegerskioeldi (Mayr, 1904)	A	parasitic/ predator	Africa	1989, ES-MAD	ES, ES-CAN, GR-CRE, PT-MAD	J2, I2, X24	Low constructed buildings, gardens	Collingwood (1993), Espadaler and Bernal (2003), Kluger (1988)
Paratrechina longicornis (Latreille, 1802)	A	parasitic/ predator	Africa	1847, ES-MAD	CH, CZ, DE, ES, ES-CAN, FI, FR, GB, IL, IT, MT, PT-AZO, PT-MAD	H, I2, J1, J100	Houses, buildings, plant cavities, trees, debris, rotten wood	Collingwood et al. (1997), Espadaler and Bernal (2003) , Freitag et al. (2000), Heinze (1986), Tinaut and Año (2000)
Paratrechina vividula (Nylander, 1846)	C	parasitic/ predator	Crypto-genic	1881, FI	CY, CZ, DE, FI, FR, GB, GR, NL, RU, SE, UA	J, J100	Constructed areas, greenhouses	Collingwood and Hughes (1987)

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Pheidole bilimeki Mayr 1870	A	parasitic/ predator	C & S America	1952, DE	CH, DE, DK, FR, GB	J100	Greenhouse	Longino and Cox (2009)
Pheidole guineensis (Fabricius, 1793)	A	parasitic/ predator	Tropical, subtropical	1883, FR	FR, DE	J100	Sparsely wooded area (N), greenhouse(I)	
Pheidole megacephala (Fabricius, 1793)	A	parasitic/ predator	Africa	1847, PT-MAD	DE, ES, ES-CAN, FR, GB, GR, GR-CRE, IT, ME, PT, PT-AZO, PT-MAD, RO, YU	I2, J1, J100	Gardens, urban	Bernard (1968), Limonta and Colombo (2003)
Pheidole noda (Smith, 1874)	A	parasitic/ predator	Asia	2003, IT	IT	I2	Nursery	Limonta and Colombo (2003)
Pheidole teneriffana Forel, 1893	A	parasitic/ predator	Africa	1893, ES-BAL	ES, ES-BAL, ES-CAN, GR, GR-CRE, GR_SEG, GR, IT-SIC	I2, X24	Disturbed areas	De Haro et al. (1986), Gomez and Espadaler (2006)
Plagiolepis alluaudi (Emery, 1894)	A	parasitic/ predator	Asia-Temperate	1915, IE	CH, DE, FR, IE	J100	Greenhouses	Geiter et al. (2002)
Plagiolepis exigua Forel, 1894	A	parasitic/ predator	Tropical, subtropical	1952, DE	DE	J100	Greenhouses	Geiter et al. (2002)
Plagiolepis obscuriscapa Santschi, 1923	A	parasitic/ predator	C & S America	Unknown	IT, RO	U	Unknown	Moscaliuc (2009)
Pyramica membranifera (Emery, 1869)	A	parasitic/ predator	Africa	1989, PT-MAD	PT-MAD	I2, X24	Gardens	Espadaler (1979), Espadaler and Lopez Soria (1991)
Strumigenys lewisi Cameron, 1886	A	parasitic/ predator	Asia	1996, MT	MT	J100	Greenhouses	Schembri and Collingwood (1995)
Strumigenys rogeri Emery, 1890	A	parasitic/ predator	Africa	Unknown	DE, GB	J100	Greenhouses	

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Strumigenys silvestrii Emery, 1906	A	parasitic/ predator	North America	1989, PT-MAD	PT-MAD	I2, X24	Gardens; predator on collembola	Geiter et al. (2002)
Tapinoma melanocephalum (Fabricius, 1793)	A	parasitic/ predator	Tropical, subtropical	1984, DE	AT, CH, DE, FI, GB, RU	J1, J100	stored products, antropophilic, indoors only	Boer and Vierbergen (2008), Espadaler and Espejo (2002), Hogmo (2003b), Jucker et al. (2008), Scheurer and Liebig (1998), Sorvari (2002), Vipin et al. (1999), Wetterer (2009b)
Technomyrmex albipes (Smith, 1861)	A	detrivorous	Asia-Tropical	1989, PT-MAD	AT, NL, PT-MAD	I2, X24, J1	Gardens, houses	Boer and Vierbergen (2008)
Technomyrmex detorquens (Walker, 1859)	A	parasitic/ predator	Asia	1937, CZ	AT, CZ, DE	J100	Greenhouses, houses	Šefrová and Laštůvka (2005)
Temnothorax longispinosus Roger, 1863	A	parasitic/ predator	North America	Unknown, ES	ES	D6	Oak and mixed woodland	
Tetramorium bicarinatum (Nylander, 1846)	A	parasitic/ predator	Asia-Tropical	2003, IT	DE, IT, PT-AZO, SE	J100	Nurseries	Högmo (2003a), Reyes and Espadaler (2005), Wetterer et al. (2004)
Tetramorium insolens (Smith, 1861)	A	parasitic/ predator	Asia, ATstralasia	Unknown	AT, FR, NL, PL	J100	Greenhouses	de Jonge (1985), Radchenko et al. (1998), Radchenko et al. (1999)
Tetramorium lanuginosum Mayr, 1870	A	parasitic/ predator	Asia	Unknown	IL, MT	J100	Greenhouses s	Reyes and Espadaler (2005), Schembri and Collingwood (1995)
Tetramorium simillimum (Smith, 1851)	A	parasitic/ predator	Tropical, subtropical	Unknown	DE, EE, FR, GB, IL, PL, PT-AZO, PT-MAD, GB	J100	Greenhouses	Bernard (1968), Wetterer et al. (2006)

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Ichneumonidae								
Auberteterus alternecoloratus (Cushman, 1929)	A	parasitic/ predator	Asia-Temperate	Unknown	FR, R	I	Stem borers (Pyralidae)	Gokhman (1996)
Cryptus luctuosus Cresson, 1864	A	parasitic/ predator	North America	Unknown	AT, FR, RU	G3	Sawflies on *Tsuga*	
Cteniscus dorsalis Cresson, 1864	A	parasitic/ predator	North America	Unknown	FR, NO	G3	Sawflies	
Delomerista novita (Cresson, 1870)	A	parasitic/ predator	North America	Unknown	AT, DE, FI, GB, NL, NO, PL, RU	G3	Sawflies (Diprionidae and others)	Hedstrom (1987), Jussila (1989), Phillips (1997)
Ephialtes spatulatus (Townes, 1960)	A	parasitic/ predator	North America	Unknown	AT, PL, RU, SE	G3	Xylophagous beetles	Hedstrom (1987)
Itoplectis conquisitor (Say,1835)	A	parasitic/ predator	North America	Unknown, DE	DE	I	Apple tortricid	Biermann (1973)
Megachilidae								
Osmia cornifrons (Radoszkowski, 1887)	A	phyto-phagous	Asia-Temperate	1970, DK	DK	I, E	Pollinator of fruit trees	Kristjansson and Rasmussen (1990)
Mymaridae								
Anaphes nitens (Girault, 1928)	A	parasitic/ predator	Australasia	1977, IT	ES, FR, IT, PT	I2	*Eucalyptus* snout-beetle *Gonipterus scutellatus (*egg Parasitoid)	Arzone and Vidano (1978), Cadahia (1986), Rivera et al. (1999), Vaz et al. (2000)
Polynema striaticorne Girault, 1911	A	parasitic/ predator	North America	1966, IT	IT	I2	*Ceresa bubalus*	Vidano (1968)
Pamphiliidae								
Cephalcia alashanica (Gussakovskij, 1935)	A	phyto-phagous	Asia-Temperate	1986, NL	NL	G3	*Picea*	Battisti and Sun (1996), Gossner et al. (2007), Holusa et al. (2007), Jachym (2007), Shinohara and Zombori (2003)

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Perilampidae								
Steffanolampus salicetum (Steffan, 1952)	A	parasitic/ predator	North America	1876, AT	AT	G	*Ptilinus* (Anobiidae)	Giraud and Laboulbène (1878)
Platygastridae								
Amitus fuscipennis MacGown & Nebeker, 1978	A	parasitic/ predator	North America	1980, IT	IT	J100	*Trialeurodes vaporariorum*	Manzano et al. (2002), Viggiani (1997), Vis and Lenteren (2008)
Amitus spiniferus (Brèthes, 1914)	A	parasitic/ predator	Tropical, subtropical	1971, FR	ES, FR, IT, IT-SIC	J100	*Aleurothrixus floccosus*	DeBach and Rose (1976a), Liotta et al. (2003)
Pteromalidae								
Anisopteromalus calandrae (Howard, 1881)	C	parasitic/ predator	Crypto-genic	1911, AT	AT, BE, CH, CZ, DE, FR, GB, GR, HU, IL, IT, PT, RO, RU, RS, SE, SK	J	Stored products beetles	Beratlief (1967), Boucek (1977b), Boucek and Graham (1978), Frilli (1965), Garrido-Torres and Nieves-Aldrey (1990), Hedqvist (2003), Kalina (1989), Mitroiu (2001), Ruschka (1912)
Halticoptera daci Silvestri, 1914	A	parasitic/ predator	Africa	1957, IT	IT	I	*Bactrocera oleae*	Thompson (1958)
Mesopolobus modestus (Silvestri, 1914)	A	parasitic/ predator	Africa	1974, IT	IT	I	*Bactrocera oleae*	Viggiani (1975a)
Mesopolobus pinus Hussey, 1960	A	parasitic/ predator	North America	1953, GB	BE, DK, FR, GB, NL, PL, SE	G3	*Megastigmus* seed chalcid in Abies seeds	Bak (1999), Pettersen (1976), Skrzypczynska (1989), Wisniowski (1987)
Mesopolobus spermotrophus Husey, 1960	A	parasitic/ predator	North America	1952, GB	BE, CZ, DE, FR, GB, IT, LU, NL, PL, SE	G3	*Megastigmus* seed chalcid in Douglas-fir seeds	Graham (1969)

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Monoksa dorsiplana Boucek, 1991	A	parasitic/ predator	C & S America	1980, IL	IL	U	Seed-beetles	Boucek (1991)
Moranila californica (Howard, 1881)	A	parasitic/ predator	Australasia	1973, IT	ES, ES-CAN, FR, GR, IL, IT, IT-SIC, IT	G, I2, F	Scales, *Quercus, Citrus, Fagus, Olea (*Highly polyphagous)	Raspi (1988), Simoes et al. (2006), Stratopoulou et al. (1981)
Muscidifurax raptor Girault & Sanders, 1910	A	parasitic/ predator	North America	1954, CZ	CZ, DE, DK, ES, IT, RO	J	*Musca domestica* and stable files	Fabritius (1978), Fabritius (1981), Rutz and Axtell (1979)
Paracarotomus cephalotes Ashmead, 1894	A	parasitic/ predator	North America	1976, FR	FR, IT, RU,			Boucek (1976), Dzhanokmen (1984)
Spalangia cameroni, Perkins 1910	A	parasitic/ predator	North America	1969, DK	CY, CZ, DE, DK, ES, IT, MD, RO, SE	J	*Musca domestica* and stable files	Falco et al. (2006), Gibson (2009), Maini and Bellini (1991), Tormos et al. (2009)
Theocolax elegans (Westwood, 1874)	C	parasitic/ predator	Crypto-genic	1957, DE	BE, DE, GR,	J	Stored products beetles	Eliopoulos et al. (2002), Mitroiu (2001), Thompson (1958)
Urolepis rufipes (Ashmead, 1896)	A	parasitic/ predator	North America	1989, DE	DE, DK, SE	J	house flies (pupae)	Gibson (2000), Hedqvist (2003), Skovgard and Jespersen (1999)
Scelionidae								
Duta tenuicornis (Dodd, 1920)	A	parasitic/ predator	Australasia	1989, HU	HU, MD	I	Crickets (Egg parasitoid)	Popovici (2005)
Gryon leptocorisae (Howard, 1885)	A	parasitic/ predator	North America	Unknown	DK, FR, IT	I	*Stenocoris* (Egg parasitoid)	Mineo (1981)
Telenomus busseolae Gahan, 1922	A	parasitic/ predator	Africa	Unknown, IT	IT	I	Stem borers (Egg parasitoid)	Conti and Bin (2000), Gullu and Simsek (1995), Laudonia et al. (1991)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Signiphoridae								
Chartocerus niger (Ashmead, 1900)	A	parasitic/ predator	North America	Unknown	ES, FR, IT	U	Scale insects (Hyperparasitoid via Encyrtids)	Woolley (1988)
Siricidae								
Sirex areolatus (Cresson, 1867)	A	phyto-phagous	North America	1995, GB	GB, IT	G3	Conifers	Viitasaari and Midtgaard (1989)
Sirex cyaneus cyaneus Fabricius, 1781	A	phyto-phagous	North America	1885, FR	BE, CH, DE, DK, FR, GB, GR, HU, IE, IL, IT, LU, NL, PT, SE, SK	G3, I2	Conifer trunks (mainly *Abies*)	Hayes (1982), Hellrigl (1984), Kirk (1974), Midtgaard (1986), Schwarz (1994), Viitasaari and Midtgaard (1989)
Tremex columba (Linnaeus, 1763)	A	phyto-phagous	North America	1957, GB	GB	G, I2	*Fagus, Quercus, Acer, Betula*, etc	Winter (1988)
Urocerus albicornis (Fabricius, 1781)	A	phyto-phagous	North America	1991, GB	GB, IS, NL, PL	G3	Conifers	Witmond (2001)
Urocerus californicus Norton, 1869	A	phyto-phagous	North America	1944, GB	GB	G3	Conifers	Fitton et al. (1978)
Sphecidae								
Isodontia mexicana (Saussure, 1867)	A	parasitic/ predator	North America	1960, FR	AT, CH, DE, ES, FR, FR-COR, HR, IT, SI	E, X25	Crickets in grasslands (predatory)	Pagliano et al. (2000), Scaramozzino and Pagliano (1987)
Sceliphron cementarium (Drury, 1773)	A	parasitic/ predator	North America	1945, FR	AT, BE, DE, ES-CAN, FR, FR-COR, HR, IT, LU, PT-MAD, PT, UA	C3, X25	Adults nectar at flowers and mud nests are built in sheltered locations such as garages and underneath bridges	Bitsch et al. (1997), Pagliano et al. (2000)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Sceliphron curvatum (Smith, 1870)	A	parasitic/ predator	Asia-Temperate	1979, AT	AT, BG, CH, ,CZ, DE, FR, FR-COR, HR, HU, IT, IT-SAR, IT-SIC,RS, SI, UA,	C3, X25	Adults nectar at flowers and mud nests are built in Sheltered locations such as garages and underneath bridges, predatory	Bitsch and Barbier (2006), Bogusch et al. (2005), Castro (2007), Cetkovic et al. (2004), Ebmer (1995), Gonseth et al. (2001), Rahola (2005), van der Vecht (1984)
Sceliphron deforme (Smith, 1856)	A	parasitic/ predator	Asia-Temperate	1998, ME	FR, ME	C3, X25	Adults nectar at flowers and mud nests are built in sheltered locations such as garages and underneath bridges, predatory	Cetkovic et al. (2004)
Tenthredinidae								
Nematus (*Pteronidea*) *tibialis* Newman, 1837	A	phyto-phagous	North America	1825, DE	AT, BE, BG, CH, CZ, DE, ES, FI, FR, GB, GR, HR, HU, IT, LT, MD, NL, PL, RO, SK, UA	G, I2	*Robinia*	Ermolenko and Sem'yanov (1981), Markó et al. (2006)
Pachynematus (*Larinematus*) *itoi* Okutani, 1955	A	phyto-phagous	Asia-Temperate	1971, AT	AT	G3, G5	*Larix*	Pschorn-Walcher and Zinnert (1971)
Torymidae								
Eridontomerus isosomatis (Riley, 1882)	A	parasitic/ predator	North America	1912, HU	CZ, HU, SK, UA	I	*Tetramesa* on Poaceae	Boucek (1968), Erdös (1954), Grissell (1995)
Megastigmus aculeatus nigroflavus Hoffmeyer, 1929	A	phyto-phagous	North America	1966, DE	BG, DE, FR, RU	F, I2, E5	*Rosa*	Roques and Skrzypczynska (2003)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Megastigmus atedius Walker, 1851	A	phyto-phagous	North America	1954, DE	CZ, DE, DK, FR, GB, PL, RU	G3, G4, X11	*Picea, Pinus strobus*	Jensen and Ochsner (1999), Roques and Skrzypczynska (2003)
Megastigmus borriesi Crosby, 1913	A	phyto-phagous	Asia-Temperate	1969, FIN-ALA	DK, FI-ALA, RU	X11	*Abies*	Annila (1970), Jensen and Ochsner (1999), Ochsner (1998)
Megastigmus lasiocarpae Crosby, 1913	A	phyto-phagous	North America	1969, FIN-ALA	FIN-ALA		*Abies*	Annila (1970)
Megastigmus milleri Milliron, 1949	A	phyto-phagous	North America	1952, GB	DK, FR, NL, GB	G3, G4, X11	*Abies*	Jensen and Ochsner (1999), Roques and Skrzypczynska (2003)
Megastigmus nigrovariegatus Ashmead, 1890	A	phyto-phagous	North America	1987, FR	FR	E5	*Rosa*	Roques and Skrzypczynska (2003)
Megastigmus pinsapinis Hoffmeyer, 1931	A	phyto-phagous	Africa	1858, FR	ES, FR, IT	G3, G4, X11	*Cedrus*	Pintureau et al. (1991), Roques and Skrzypczynska (2003), Skrzypczynska and Mazurkiewicz (2002)
Megastigmus pinus Parfitt, 1857	A	phyto-phagous	North America	1931, GB	BE, CZ, DE, DK, FR, GB, IE, NL, SE	G3, G4, X11	*Abies*	Jensen and Ochsner (1999), Roques and Skrzypczynska (2003)
Megastigmus rafni Hoffmeyer, 1929	A	phyto-phagous	North America	1930, GB	BE, DE, DK, FR, GB, NL	G3, G4, X11	*Abies*	Jensen and Ochsner (1999), Roques and Skrzypczynska (2003)
Megastigmus schimitscheki Novitzky, 1954	A	phyto-phagous	Asia-Temperate	1990, FR	FR	G3, G4	*Cedrus*	Roques and Skrzypczynska (2003)
Megastigmus specularis Walley, 1932	A	phyto-phagous	North America	1920, FIN-ALA	DK, FI, FR, RU, SE	G3, G4, X11	*Abies*	Jensen and Ochsner (1999), Roques and Skrzypczynska (2003)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Megastigmus spermotrophus Wachtl, 1893	A	phyto-phagous	North America	1896, GB	AT, BE, CH, CZ, DE, DK, EE, ES, FI, FR, GB, HU, IE, IT, ME, NL, NO, PL, PT, RO, RS, RU, SE, SK, UA	G3, G4, X11	*Pseudotsuga*	Mailleux et al. (2008), Roques and Skrzypczynska (2003)
Megastigmus transvaalensis (Hussey, 1956)	A	phyto-phagous	Africa	1962, ES-CAN	ES, ES-CAN, FR, PT	I2, G5	*Schinus*	Grissell and Prinsloo (2001), Scheffer and Grissell (2003)
Trichogrammatidae								
Megaphragma mymaripenne Timberlake, 1924	A	parasitic/ predator	Asia-Tropical	1995, IT	IT-SIC, IT	I	Thrips (Egg parasitoid)	Sinacori et al. (1999), Viggiani and Bernardo (1996)
Oligosita distincta (Silvestri, 1915)	A	parasitic/ predator	Africa	1939, FR	FR, SE	I	Leafhoppers (Egg parasitoid)	Hedqvist (2003), Nowicki (1940)
Oligosita sanguinea (Girault, 1911)	A	parasitic/ predator	North America	1949, HU	HU	I	Cicadellid in wheat (Egg parasitoid)	Erdös (1956)
Trichogramma achaeae Nagaraja & Nagarkatti, 1970	A	parasitic/ predator	Asia	1987, FR	FR	I	Stem-borer (Egg parasitoid)	Voegelé et al. (1988)
Trichogramma chilonis Ishii, 1941	A	parasitic/ predator	Asia	1985, DE	DE, RO	I1	Cabbage moths, cotton bollworm, maize pyralid, armyworm	Glas and Hassan (1985)
Trichogramma dendrolimi Matsumura, 1926	A	parasitic/ predator	Asia	1978, BG	AT, BE, BY, BG, DE, FR, GR, HU, IT, LT, LV, MD, RO, RU, UA	I, G	Lepidoptera, e.g. *Epichoristodes acerbella*	Babi et al. (1984), Wetzel Dickler (1994)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trichogramma minutum Riley, 1871	C	parasitic/ predator	Crypto-genic	1957, CZ	CZ, DE, ES, FR, GB, GR, IT	I1, G	Maize borer and forest moths	CIBC (1976), Herting (1975), Thompson (1958), Viggiani and Laudonia (1989)
Trichogramma perkinsi Girault, 1912	A	parasitic/ predator	Asia	1984, FR	FR	I1	Lepidopteran pests (highly polyphagous)	Voegelé et al. (1988)
Trichogramma pretiosum Riley, 1879	C	parasitic/ predator	Crypto-genic	1975, GR	ES, GR, YU	I1	Cotton leafworm	Danon (1989), Stavraki (1976)
Uscana johnstoni (Waterston, 1926)	A	parasitic/ predator	Africa	1970, RO	RO	J	Bruchinae	Botoc (1971)
Uscana semifumipennis Girault, 1911	A	parasitic/ predator	North America	1963, HU	HU	J	Bruchinae	Reichart (1964)
Vespidae								
Vespa velutina nigrithorax du Buysson, 1905	A	parasitic/ predator	Asia-Temperate	2004, FR	FR	G	Woodland	Haxaire et al. (2006), Villemant et al. (2006)

Table 12.2. Hymenoptera species alien *in* Europe. List and characteristics. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 01/03/2010.

Families *Species*	**Status**	**Regime**	**Native range**	**First Record**	**Invaded countries**	**Habitat**	**Host**	**References**
Aphelinidae								
Eretmocerus mundus Mercet, 1931	E	parasitic/ predator	Medi-terranean region	Unknown	DE, NL	J100	Cotton whitefly, *Bemisia*, *Trialeurodes*	Drost et al. (1996)
Apidae								
Apis mellifera carnica (Pollmann, 1879)	E	phyto-phagous	Europe	2001, DK	DK, PT	I	Pollinator of various cultivated plants	Pedersen (1996)
Apis mellifera ligustica (Spinola, 1806)	E	phyto-phagous	Europe	1987, DK	DK, PT	I	Pollinator of various cultivated plants	Pedersen (1996)
Apis mellifera mellifera Linnaeus, 1758	E	phyto-phagous	Europe	2005, AL	AL, GL	I	Pollinator of various cultivated plants	
Bombus hortorum (Linnaeus, 1761)	E	phyto-phagous	Europe	1959, IS	IS	I	Pollinator of various cultivated plants	Prys-Jones et al. (1981)
Bombus lucorum (Linnaeus, 1761)	E	phyto-phagous	Europe	1979, IS	IS	I	Pollinator of various cultivated plants	Prys-Jones et al. (1981)
Argidae								
Arge berberidis Schrank, 1802	E	phyto-phagous	Europe	2000, GB	GB	I2	*Berberis*	Fitton et al. (1978)
Bethylidae								
Sclerodermus domesticus Klug, 1809	E	parasitic/ predator	Europe	2005 PT-AZO	PT-AZO, GB	J	Insects in wood furnitures; cause dermatitis in human by stings	Fitton et al. (1978)
Blasticotomidae								
Blasticotoma filiceti Klug 1834	E	phyto-phagous	Europe	1905, GB		I2, D2	*Athyrium* ferns (Leaf miner)	Schedl (1974)

Families *Species*	Status	Regime	Native range	First Record	Invaded countries	Habitat	Host	References
Chrysididae								
Chrysis marginata Mocsary, 1889	E	parasitic/ predator	Asia-Temperate	1915, HU	AT, HR, HU, IT	F6	Bees	Pagliano et al. (2000)
Cynipidae								
Andricus corruptrix (Schlechtendal, 1870)	E	phyto-phagous	Europe	1735, GB	GB, IE	G	*Quercus*	Fitton et al. (1978)
Andricus grossulariae Giraud,1859	E	phyto-phagous	Europe	Unknown, GB	GB	G,I2	*Quercus*	Fitton et al. (1978)
Andricus kollari (Hartig 1843)	E	phyto-phagous	Europe	1735, GB	GB	G	*Quercus*	Fitton et al. (1978)
Andricus lignicola (Hartig,1840)	E	phyto-phagous	Europe	1735, GB	GB	I2	*Quercus*	Fitton et al. (1978)
Andricus quercuscalicis (Burgesdorff 1783)	E	phyto-phagous	Europe	Unknown	GB, IE	I2	*Quercus*	Fitton et al. (1978)
Aphelonyx cerricola (Giraud 1859)	E	phyto-phagous	Europe	1993, GB	GB	G	*Quercus*	Fitton et al. (1978)
Diprionidae								
Diprion pini (Linnaeus, 1758)	E	phyto-phagous	Europe	Unknown, IE	IE	G3	*Pinus*	Fitton et al. (1978)
Diprion similis (Hartig, 1836)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Pinus*	Fitton et al. (1978)
Gilpinia hercyniae (Hartig, 1837)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Picea*	Fitton et al. (1978)
Gilpinia virens (Klug, 1812)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Pinus*	Fitton et al. (1978)
Neodiprion sertifer (Geoffroy, 1785)	E	phyto-phagous	Europe	Unknown	IE, GB	G3	*Pinus*	Fitton et al. (1978)

Families *Species*	Status	Regime	Native range	First Record	Invaded countries	Habitat	Host	References
Encyrtidae								
Ageniaspis fuscicollis (Dalman, 1920)	E	parasitic/ predator	Mediterranean region	1735, GB	AU, BE, BY, CH, CZ, DE, DK, EE, ES-CAN, FI, GB, HU, IS, IE, LT, LV, LU, MD, NL, NO, NO-SVA, PL, PT-AZO, PT-MAD, RO, RU, SE, SK, UA	I	*Prays oleae* on *Citrus* and yponomeutids	Koscielska (1963), Kuhlmann (1994), Nénon (1978)
Anagyrus pseudococci (Girault, 1915)	E	parasitic/ predator	Mediterranean region	1994, PT	CZ, ES-CAN, FR, HR, IL, MD, ME, NL, PT, RU, SE, YU	J100	Pseudococcids on *Citrus* and many crops	Tingle and Copland (1988)
Eulophidae								
Thripastichus gentilei (Del Guercio, 1931)	E	parasitic/ predator	Europe	1930, IT	DE, FR, IT, YU	I	Thrips	Del Guercio (1931), Domenichini et al. (1964), Herting (1971)
Eurytomidae								
Bruchophagus robiniae Zerova, 1970	E	parasitic/ predator	Europe	1969, UA	BG, UA,	G5	Seed feeder on *Robinia pseudoacacia*	Stojanova (1997), Zerova (1970)
Formicidae								
Aphaenogaster senilis Mayr, 1853	E	parasitic/ predator	Mediterranean region	2005, PT-AZO	PT-AZO,	U	Natural habitat, garrigue	Wetterer et al. (2004)
Crematogaster scutellaris (Olivier, 1792)	E	parasitic/ predator	Europe	Unknown	DE, GB	J	Trees	Bernard (1968)
Lasius alienus (Foerster, 1850)	E	parasitic/ predator	Europe	Unknown, IE	IE	E1, H5	Warm, dry, stony environnements	Collingwood (1958)
Lasius flavus (Fabricius, 1781)	E	parasitic/ predator	Europe	Unknown, IE	IE	E1, E5	Meadows, dry grasslands, Forest borders	Collingwood (1958)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record**	**Invaded countries**	**Habitat**	**Host**	**References**
Lasius fuliginosus (Latreille, 1798)	E	parasitic/ predator	Europe	Unknown, IE	IE	E5	Trunks and stumps, forest borders	Edwards (1997)
Ponera coarctata (Latreille, 1802)	E	parasitic/ predator	Mediterranean region	Unknown	BE, BG, DE, GB, HU, PL, RU	G	Dry and warm areas	Geiter et al. (2002)
Tetramorium caldarium (Roger, 1857)	E	parasitic/ predator	Europe	1847, PT-MAD	ES-CAN, GB, PT-AZO, PT-MAD	G, J1, I2	Gardens, urban, arid sites	Wetterer et al. (2004)
Megachilidae								
Megachile rotundata (Fabricius, 1787)	A	phytophagous	Europe	Unknown	RU	I	Pollinator of alfalfa	Pesenko and Astafurova (2003)
Pamphiliidae								
Acantholyda erythrocephala L. 1758	E	parasitic/ predator	Europe	Unknown	GB	G3	*Pinus*	Fitton et al. (1978)
Acantholyda (*Itycorsia*) *laricis* (Giraud, 1861)	E	phytophagous	Europe	1986, NL	BE, NL	G3	*Larix*	Magis (1988)
Cephalcia abietis (Linnaeus, 1758)	E	phytophagous	Europe	1986, NL	NL	G3	*Picea*	van Achterberg and van Aartsen (1986)
Cephalcia alpina (Klug, 1808)	E	phytophagous	Europe	1988, BE	BE, LU	G3	*Picea*	Magis (1988)
Cephalcia erythrogaster (Hartig, 1837)	E	phytophagous	Europe	1986, NL	BE, NL	G3	*Picea*	Magis (1988)
Cephalcia lariciphila (Wachtl, 1898)	E	phytophagous	Europe	1941, NL	BE, DK, GB, LT, NL, SE, UA	G3	*Larix*	Billany and Brown (1980)
Pteromalidae								
Lariophagus distinguendus (Förster, 1841)	E	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	J	Stored products weevils, *Sitophilus*, in grain	
Siricidae								
Sirex juvencus (Linnaeus, 1758)	E	phytophagous	Europe	Unknown, GB	GB	G3	Conifers	Fitton et al. (1978)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record**	**Invaded countries**	**Habitat**	**Host**	**References**
Sirex noctilio Fabricius, 1773	E	phyto-phagous	Europe	Unknown	GB	G3	*Pinus, Abies, Larix*	Fitton et al. (1978)
Urocerus gigas (Linné, 1758)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	Conifers	Fitton et al. (1978)
Xeris spectrum (Linnaeus, 1758)	E	phyto-phagous	Europe	1951, GB	GB	G3	Conifers	Fitton et al. (1978)
Tenthredinidae								
Ametastegia (Protemphytus) pallipes (Spinola, 1808)	E	phyto-phagous	Europe	Unknown, GB	GB	I2	*Viola*	Fitton et al. (1978)
Anoplonyx destructor Benson, 1952	E	phyto-phagous	Europe	1953, GB	DK, EE, GB, HU, IE, SE	G3, I2	*Larix*	Leston (1988), Piekarczyk and Wright (1988), Speight (1979)
Athalia rosae (Linnaeus, 1758)	E	phyto-phagous	Europe	Unknown, GB	GB	I,J	*Brassica, Sinapis*	Fitton et al. (1978)
Hoplocampa brevis (Klug, 1816)	E	phyto-phagous	Europe	1935, GB	GB	I2, G5	*Pyrus*	Fitton et al. (1978)
Nematus (Pteronidea) spiraeae Zaddach, 1883	E	phyto-phagous	Europe	1824, GB	GB	I2	*Spiraea, Aruncus*	Fitton et al. (1978)
Pachynematus (Epicenematus) montanus (Zaddach, 1883)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Picea*	Fitton et al. (1978)
Pachynematus (Larinematus) imperfectus (Zaddach, 1876)	E	phyto-phagous	Europe	1915, DK	BE, DK, GB, HU, LV, NL	G3, G5	*Larix*	Fitton et al. (1978)
Pachynematus (Pikonema) scutellatus (Hartig, 1837)	E	phyto-phagous	Europe	Unknown	GB, IE	G3	*Picea*	Fitton et al. (1978)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record**	**Invaded countries**	**Habitat**	**Host**	**References**
Pachyprotasis variegata (Fallen, 1808)	E	phyto-phagous	Europe	Unknown, GB	GB	I,J	*Digitalis, Plantago*	Fitton et al. (1978)
Phymatocera aterrima (Klug, 1816)	E	phyto-phagous	Europe	1846, GB	GB	I2, G1	*Polygonatum*	Fitton et al. (1978)
Pristiphora (*Lygaeonematus*) *abietina* (Christ, 1791)	E	phyto-phagous	Europe	Unknown, IE	IE	G3	*Picea*	
Pristiphora (*Lygaeonematus*) *compressa* (Hartig, 1837)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Picea*	Fitton et al. (1978)
Pristiphora (*Lygaeonematus*) *erichsonii* (Hartig, 1837)	E	phyto-phagous	Europe	1906, GB	DK, EE, ES, GB, IE, LV, NL, NO, SE	G3, I2, FB	*Larix*	Fitton et al. (1978)
Pristiphora (*Lygaeonematus*) *glauca* Benson, 1954	E	phyto-phagous	Europe	1954, GB	GB	G3	*Larix*	Fitton et al. (1978)
Pristiphora (*Lygaeonematus*) *saxesenii* (Hartig, 1837)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Picea*	Fitton et al. (1978)
Pristiphora (*Lygaeonematus*) *subarctica* (Forsslund, 1936)	E	phyto-phagous	Europe	1949, GB	GB	G3	*Picea*	Fitton et al. (1978)
Pristiphora (*Lygaeonematus*) *wesmaeli* (Tischbein, 1853)	E	phyto-phagous	Europe	1915, DK	BE, BY, DK, EE, GB, NL, SE, GB	G3, I2, FB	*Larix*	Fitton et al. (1978)
Pristiphora (*Oligonematus*) *laricis* (Hartig, 1837)	E	phyto-phagous	Europe	1915, DK	BE, DK, EE, ES, GB, HU, IE, ME, NL, RS, SE, UA	G3, FB, I2	*Larix*	Fitton et al. (1978)

Families *Species*	Status	Regime	Native range	First Record	Invaded countries	Habitat	Host	References
Pristiphora (*Pristiphora*) *angulata* Lindqvist, 1974	E	phyto-phagous	Europe	1995, FI	EE, FI	FA, I2	*Spiraea chamaedryfolia*	Lindqvist (1974)
Pristiphora (*Pristiphora*) *leucopus* (Hellén, 1948)	E	phyto-phagous	Europe	2004, GB	GB	G3, G4	*Tilia*	Fitton et al. (1978)
Pristiphora (*Pristiphora*) *thalictri* (Kriechbaumer, 1884)	E	phyto-phagous	Europe	1946, GB	GB	I2	*Thalictrum*	Fitton et al. (1978)
Pristiphora (*Sharliphora*) *amphibola* (Förster, 1854)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Picea*	Fitton et al. (1978)
Pristiphora (*Sharliphora*) *nigella* Förster, 1854)	E	phyto-phagous	Europe	Unknown, GB	GB	G3	*Picea*	Fitton et al. (1978)
Torymidae								
Megastigmus pictus (Förster, 1841)	E	phyto-phagous	Europe	1879, GB	IE, GB	G3, G4,X11	*Larix*	Roques and Skrzypczynska (2003)
Megastigmus suspectus Borries, 1895	E	phyto-phagous	Europe	1943, IE	IE, GB	G3, G4,X11	*Abies*	Roques and Skrzypczynska (2003)
Megastigmus wachtli Seitner, 1916	E	phyto-phagous	Asia-Temperate	1915, SI	AL, BA, BG, ES, FR-COR, FR, GR, HR, IL, IT, ME, MT, PT, RO, RS, SI	G5, I2, X15	*Cupressus*	Rasplus et al. (2000), Roques and Skrzypczynska (2003)
Trichogrammatidae								
Trichogramma brassicae Bezdenko, 1968	E	parasitic/ predator	Europe	1996, DE	AT, BG, CH, DE, ES, FR, NL, RO	I1	*Ostrinia* corn borer but highly polyphagous	Pintureau (2008)
Vespidae								
Vespula germanica (Fabricius, 1793)	E	parasitic/ predator	Europe	Unknown, IS	IS	G3, G4	Woodland	Olafsson (1979)
Vespula vulgaris (Linné, 1758)	E	parasitic/ predator	Eurasia	Unknown	FÖ, IS	H, X25	Woodland	Olafsson (1979)

Table 12.3. Number of alien Hymenoptera per European countries.

Countries	N	Countries	N
Italy mainland	144	Finland mainland	13
France mainland	111	Italy Sardinia	13
Spain mainland	90	Montenegro	11
Israel	82	Spain Balearic islands	11
Germany mainland	80	Croatia	10
Greece mainland	50	Norway mainland	10
Great Britain	45	Ireland	10
Czech Republic	41	Malta	8
Netherlands	40	Moldova	8
Denmark	36	Slovenia	8
Italy Sicily	36	Lithuania	7
Portugal mainland	35	Portugal Azores	7
Russia	33	Greece Crete	6
Belgium	32	Estonia	5
Austria	31	Luxemburg	4
Hungary	30	Greenland	3
Spain Canary islands	30	Iceland	2
Switzerland	30	Belarus	2
Poland	26	FinlandAland	2
Sweden	23	Greece South Aegean Isl	2
Cyprus	23	Latvia	1
Bulgaria	22	Bosnia	1
Ukraine	22	Feroe Islands	1
France Corsica	19	Greece North Aegean Isl	1
Romania	18	Norway Svalbard	1
Portugal Madeira	18	Andorra	0
Slovakia	18	FYRM Macedonia	0
Albania	17	Greece Ionian islands	0
Former Yougoslavia	14	Lichtenstein	0
Serbia	14		

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Thrips (Thysanoptera) Chapter 13.1

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Abstract

Thrips (Order Thysanoptera) are found worldwide and include almost 6000 species. Several of them are notorious for causing extensive crop damage (by feeding on leaf tissue or by vectoring viral disease). Their small size (usually less than 2 millimeters) and cryptic habits have facilited invasions and establishment in Europe in the wild or in greenhouses. Fifty-two alien species, belonging to four families have been recorded within Europe. Species introduced before 1950 mostly originate from America, tropical and subtropical areas and subsequent arrivals generally originate from Asia (and from America to some extent). Five countries host more than 30% of the European alien thrips fauna and two alien thrips occur in more than 50% of the countries and islands of Europe.

Keywords

Thysanoptera, thrips, alien, Europe

13.1.1. Introduction

Thrips (Order Thysanoptera) are ubiquitous, small to minute (a few millimeters long) and slender-bodied insects with fringed wings. The morphology is reduced: thrips have only one functional mandibular stylet, the second being greatly reduced, thus forming asymmetrical suctorial mouthparts compacted within a short cone-shaped rostrum. About 50% of the known species of Thysanoptera feed on fungi, approximately 40% feed on living tissues of dicotyledonous plants or grasses, and the remainder exploit mosses, ferns, gymnosperms, cycads, or are predatory (Morse and Hoddle 2006). Less than 1% of described thrips species are serious pests and most economic literature deals with just four species (Mound and Teulon 1995).

The almost 6000 known species of thrips are at present arranged into two suborders (Terebrantia and Tubulifera) and nine families, but disagreement exists concerning the family classification system (Mound 2007). Phlaeothripidae is the largest family and the sole family in the suborder Tubulifera with about 3500 described species (Mound and Morris 2007). The other eight families are all included in the suborder Terebrantia (2400 species). Members of the Merothripidae (15 species) and Uzelothripidae (1 species) are all very small thrips associated with fungal hyphae in warm countries. In contrast, members of the Melanthripidae (65 species) are usually large and robust, and they all breed in flowers, and occur in temperate areas. The Aeolothripidae (190 species) is a rather larger family of mainly phytophagous species feeding on flowers, or non-obligate predators of other arthropods. The species of the next three families are poorly known, Fauriellidae (5 species) from California, southern Europe and South Africa. Adiheterothripidae (6 species) are known only from the flowers of date palms, *Phoenix dactylifera* and Heterothripidae (71 species), are found only in the New World and, with one exception, all species live within flowers. The eighth family, with nearly 2100 known species is by far the largest within Terebrantia : Thripidae are found worldwide and include almost all of the pest species of thrips, many of them feed and breed on both leaves and in flowers.

13.1.2 Taxonomy of the Thysanoptera species alien *to* Europe

The 52 species of Thysanoptera alien *to* Europe belong to four different families (Table 13-1) but two of them (Phlaeothripidae and Thripidae) include more than 99% of the alien species.

Suborder Tubulifera

Phlaeothripidae: The traditional classification of Tubulifera comprises a single family with two subfamilies. All members of the smaller subfamily, the Idolothripinae, feed on fungal spores and live on dead twigs, in leaf litter or within the bases of grass and sedge tussocks. The spore-feeding *Nesothrips propinquus* is the unique alien species among less than 30 european species and is widely distributed in countries occuring along the sailing route from New Zealand to Europe, presumably in hay and straw (Mound 2006). It can be found on citrus fruits in its native habitat but there is no evidence of producing any damage (Blank and Gill 1997). Phlaeothripinae is the main subfamily of Phlaeothripidae, with 2800 species (Mound and Morris 2007). They exhibit a wide range of biologies: a few are predatory, some are flower feeders but in most cases, they are leaf feeding or associated with fungi in leaf litter or on dead wood. Fourteen species belonging to ten genera are here considered to be alien species in Europe (from a total of around 180 native species). Among them, five species prey upon small arthropods (including scale insects), five species are detrivorous and four species are known to be phytophagous, including *Gynaikothrips ficorum* which is recognized as a pest on *Ficus* (preferred host) and other hosts.

Suborder Terebrantia

Merothripidae: This family of three genera, with 15 fungus-feeding species that live on dead twigs and in leaf-duff, is found mainly in the Neotropics (Hoddle et al. 2004). *Merothrips floridensis* is the unique representant of this family in Europe. This is an interesting example of a small and usually wingless species with a scattered distribution, probably associated with trading routes and commercial traffic of hay, dead wood and living plants (Mound 1983).

Aeolothripidae: Until recently, Melanthripidae was included in this family. However, a morphology-based distinction with the Aeolothripidae is now well supported (Mound and Morris 2007). Typical Aeolothripidae are generally regarded as facultative predators on other small arthropods but with a few exceptions. They are mainly distributed in the temperate parts of the world, although members of several genera are restricted to the tropics. This is the case of the two alien species of ant-mimicking thrips (*Franklinothrips vespiformis* and *Franklinothrips megalops*) recorded in Europe, that have been marketed or tested as biocontrol agents in glasshouses (Mound and Reynaud 2005).

Thripidae: Four sub-families are currently recognized worldwide. Each of these is represented by alien species in Europe. <u>Dendrothripinae</u> are small in size and live on young leaves. They have been defined by the presence of a remarkably elongate metasternal endofurca associated with a jumping habit. There are two alien species, *Leucothrips nigripennis* and *Pseudodendrothrips mori*, compared to eight native species. <u>Panchaetothripinae</u> are strongly reticulate thrips and are regarded as leaf feeders with a tropical or subtropical distribution. They are well represented amongst alien species (eight species) because they are able to breed on ornemental plants in European greenhouses. There are no native species in Europe with one exception in the canary Islands and Madeira. <u>Sericothripinae</u> are a small sub-family in Europe with only two genera and eight species, including one recently described alien (*Neohydatothrips samayunkur*). The species are all phytophagous in flowers and on leaves. The subfamily <u>Thripinae</u> is the main sub-family in Europe with 59 genus and more than 240 native species and the main group of aliens in Thysanoptera with 18 genera and 24 species. Thripinae feed and breed both on leaves and in flowers and a few are specialized predators. Some thrips species transmit plant viruses. They are all included in this subfamily. Thrips-transmitted viruses can cause significant diseases of many crop plants and their impact worldwide is immense. In Europe, seven thrips species are known vectors of

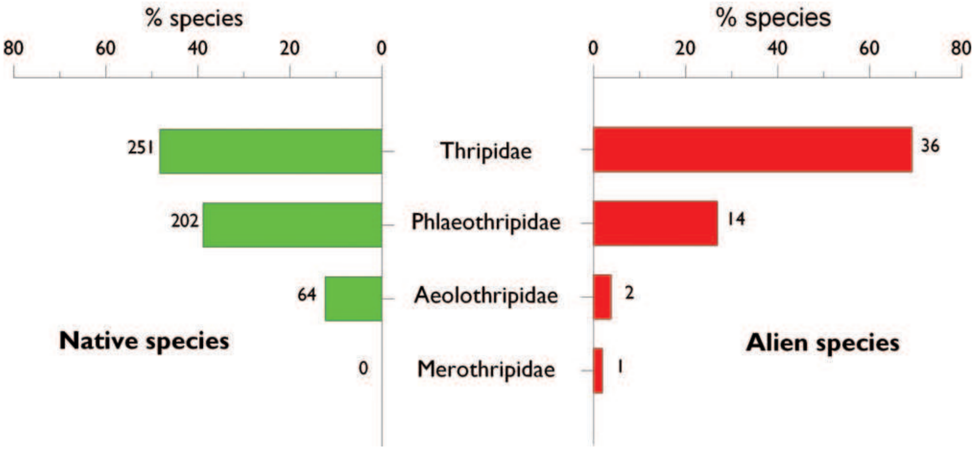

Figure 13.1.1. Relative importance of the families of Thysanoptera in the alien and native entomofauna in Europe. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of species observed per family.

virus including five alien species: three species of *Frankliniella*, one species of *Thrips* and *Microcephalothrips abdominalis* (Jones 2005). Western flower thrips, *Frankliniella occidentalis* is one of the most important pests of greenhouse crops, especially in ornamental species.

13.1.3 Temporal trends of introduction in Europe of alien thrips

Because of their small size, ability to reach high numbers, cryptic behavior, egg deposition inside plant tissue (e.g., all Terebrantia), and a propensity to secrete themselves in tight spaces (Morse and Hoddle 2006), thrips remain inconspicuous insects. The accurate recognition of alien Thysanoptera species is also a major challenge because of the difficulty of a morphometric identification (close morphological similarity) for non-specialists. There is also a lack of taxon specialists that are needed to study newly recorded species, confounded by the lack of identification keys in local monographs. Thrips identification requires significant experience, encyclopaedic knowledge, a good reference collection and relevant literature. Molecular and visual online-identification tools of the main pest thrips are now available but are not yet widely used.

For the reason above, it is likely that the real number of of alien thrips species present in Europe is greatly underestimated. The date of the first record in Europe is also unknown for seven species (13.5%). The first alien thrips species (*Heliothrips haemorrhoidalis*, called the greenhouse thrips) was discovered and originally described by Bouché in Germany in the first half of the 19th century from specimens taken from a greenhouse. This species was probably introduced into Europe on ornamental plants from tropical America. *H. haemorrhoidalis* is now widespread in Europe indoors and can be found outdoors in the southern countries. Before the First World War, seven different tropical thrips were recorded as minor pests or useful predators, always collected under protected conditions. The first outdoor alien species collected in Europe was the Thripinae *Stenchaetothrips biformis*, a major pest of rice in Asia, described in England and collected later in several european countries. *S. biformis sensu stricto* is common in vegetative shoots of *Phragmites australis* in temperate Europe, even though *S. biformis* 'rice form' is common on *Oryza sativa* in Asia and South America (Vierbergen 2004).

From 1950, a clear acceleration of thrips introductions is evident (Figure 13.1.2), with a new alien species every two years on average and as many as one new alien species per year during the period 1975 - 1999. The main event during this period was the occurrence of the western flower thrips *Frankliniella occidentalis* in the Netherlands in 1983, originating from western North America. By 1986, it was reported in Sweden and Denmark and, by 1987, it had reached France and Spain. Since then, it has been reported from most European countries and has become a major pest of agricultural and horticultural crops throughout. Since 2000, three non-native Thysanoptera are recorded, with a somewhat smaller rate of discovery compared with the previous period.

13.1.4. Biogeographic patterns of the thrips species alien to Europe

13.1.4.1 Origin of alien species

Exact knowledge of the geographical origin of alien thrips species is a vital step in enforcement of scientifically based plant quarantine and free trade protocols. Unfortunately, the area of origin of alien thrips remains unclear in 13.5% of cases. Many alien species were first described in Europe, but were undoubtedly native from other continents. Kelly's citrus thrips (KCT) was thus first collected in October 1914 in Queensland (Australia), described as *Physothrips kellyanus* by Bagnall in 1936 and known only from Australia in the last 36 years. After taxonomic studies, KCT was transferred to *Pezothrips*, a new genus including nine Palaearctic species. The morphological similarity of KCT to the eight *Pezothrips* species from the southern Palaearctic suggests that *P. kellyanus* itself originated in that part of the world. But KCT is not known to breed on any endemic plant in Mediterranean countries even when KCT larvae and adults have been found on australian endemic plants such as *Myoporum insulare* (Myoporaceae) (Webster et al. 2006). KCT is a good example of a thrips species with an unclear origin. The spread may have had more than one origin and the source of reintroductions of many plant pests and pathogens has changed over time. For example, *Frankliniella occidentalis* originally from the USA, was introduced to the UK from the Netherlands, and is reintroduced from several tertiary sources, such as Kenya (Perrings et al. 2005).

Alien thrips come mainly (65.4%) from Asia, Central and South America and North America (Figure 13.1.3). Temporal analysis shows that Central and South America and Africa were the main source of introductions before 1900, followed by species

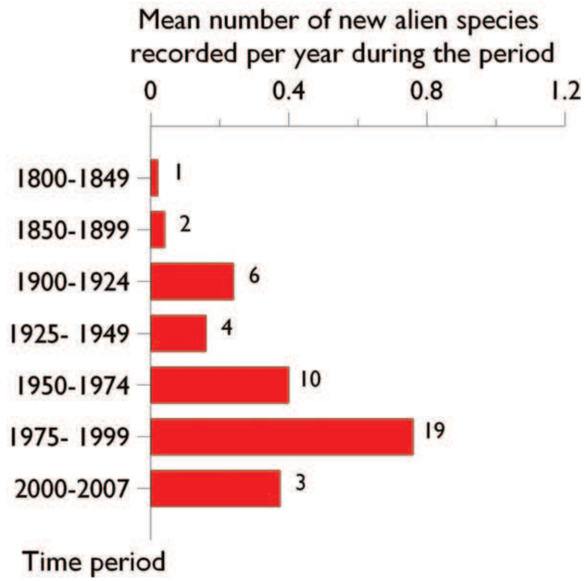

Figure 13.1.2. Temporal changes in the mean number of records per year of Thysanoptera species alien *to* Europe from 1492 to 2007. The number over each bar indicates the absolute number of species newly recorded per time period.

of mainly tropical, subtropical and Australasian origins between 1900 and 1950. After that date, non-indigenous thrips mostly originate from Asian and secondarily from North America.

13.1.4.2 Distribution of alien species in Europe

Figure 13.1.4 presents the colonization of European countries and main islands by alien thrips. Countries can be divided into the following categories:

- 13 countries with no known alien species. They include particulary small countries, some small southern islands, northern islands and a large northern country, Belarus.
- 21 countries which host less than 10% of the known invasive thrips in Europe. This category comprises large countries, probably poorly sampled by entomologists (Greece) or northern countries (Poland, Ukraine, Austria) and large islands which have been poorly surveyed.
- 17 countries with 10% to 30% of the known invasive thrips. This group generally consist of large countries (Germany, Spain, Sweden, Norway, Finland) but also includes small southern islands (Azores, Madeira, Canary islands) well sampled by entomologists and with a favourable climate for exotic thrips.
- 5 countries with more than 30% of the known European alien thrips fauna. Three large countries are involved, two with varied but favourable climate (Italy and France) and two with a long tradition of thysanopterologists (Great Britain and

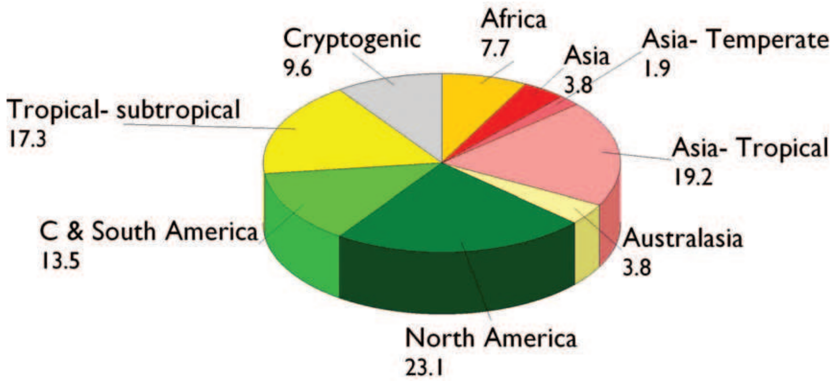

Figure 13.1.3. Origin of the 52 alien species of Thysanoptera established in Europe. Numbers indicate the relative proportion of alien species originating from a given region.

Germany). Lastly, Netherlands, owing to its open economy and international trade, records 20 alien thrips species.

Surprisingly, there is no significant relationship between country surface area and number of alien species (Figure 13.1.5, $r^2 = 0.2522$). For instance, Netherlands and Italy harbour the same number of non-native thrips, but Netherland surface is only 14% of of the area of Italy.

Only two alien thrips (*Frankliniella occidentalis* and *Heliothrips haemorrhoidalis*) occur in more than 50% of the countries and islands of Europe and a quarter of the species are known from a single country. There is no clear relationship between the date of first record and the number of contaminated countries.

13.1.5. Pathways of introduction in Europe of alien thrips species

Adults and larvae of Thysanoptera are very small, highly thigmotactic, and often lay minute eggs within plant material (e.g. petioles, stems, leaves and fruit) making rapid visual detection impossible. As a consequence, accidental introduction in Europe is the rule for non-native Thysanoptera (94%) and intentional introduction is confirmed for only three species (*Franklinothrips vespiformis*, *Franklinothrips megalops* and *Karnyothrips melaleucus*). The global trade in ornamental greenhouse plants is clearly the main pathway for non-native thrips: all widespread alien species in Europe are greenhouse pests or predators. It also means that after introduction, domestic trade of ornamental plants inside Europe is a major pathway for the transport of thrips. Greenhouse environments eliminate climatic barriers to establishment (e.g., *H. haemorrhoidalis*) and may also provide important overwintering sites from which outdoor populations establish in spring to attack vegetable crops (e.g., *F. occidentalis* in northern Europe) (Morse and Hoddle 2006).

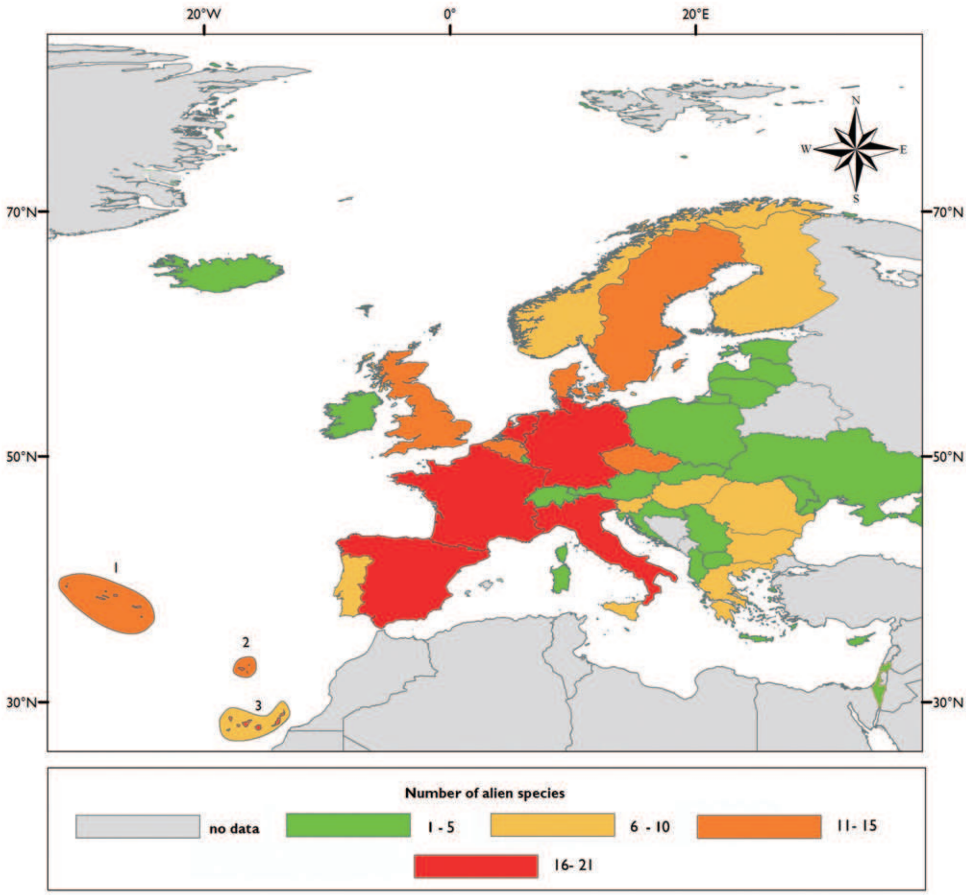

Figure 13.1.4. Comparative colonization of continental European countries and islands by the thrips species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

13.1.6. Ecosystems and habitats invaded in Europe by alien thrips species

Although thrips are known as inhabitants of flowers, they are also abundant and diverse in other microhabitats. They are phytophagous insects, sap suckers (some of which feed on aquatic plants), but can also work as decomposers, fungivores, pollinators, predators on insects and mites, whilst one species was recently discovered as an ectoparasite under the wings of a bug.

Alien thrips are mostly phytophagous (75%) and seldom predators (13.5%) or detritivores (11.5%). Cultivated habitats are preferentially (94.2%) invaded by exotic thrips, including greenhouses that provide suitable habitat for 55.8% of the invasive species in Europe (Figure 13.1.5).

Nevertheless, we can assume that thrips species such as spore and fungal feeders are underestimated in faunal studies, because these ecosystems are usually less investigated by thysanopterologists. Similarly, the wild flora that surrounds areas of crops is rarely

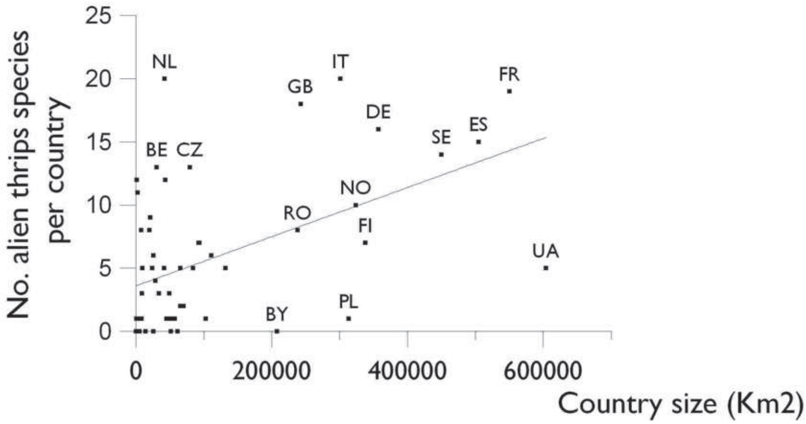

Figure 13.1.5. Relationships bewteen the size of the European countries and the number of alien Thysanoptera observed in the country. best fit: Y= 2E-05x + 3.5957; r= 0.2522)

sampled. It may also be important in facilitating the spread and colonization of new ecosystems. The remaining habitats (13.5%) include deciduous wooded habitats, dry grasslands or unknown habitats.

13.1.7. Ecological and economic impact of alien thrips species

Three major food sources are used by thrips: fungal hyphae and spores, green leaves, and flowers with or without leaves as well. A few species are also predators, and a very few feed only on mosses (Mound and Marullo 1996). More than 95% of Terebrantia are associated with vascular plants, whereas about 60% of Tubulifera species are fungivores (Mound 2002). But of an estimated 8000 extant species of thrips (Lewis 1997) and more than 5500 species that are described, scarcely 1% are recorded as serious pests, mainly in the Thripidae family.

Thrips can affect plants by direct feeding, which may leave visible signs of damage, such as leaf silvering. Many tubuliferans also cause galls[1]. A few thrips transmit plant viruses and can cause significant diseases of many crop plants and their impact worldwide has been judged to be substantial (Jones 2005). Thrips can also be considered as pests through their habit of crawling into small spaces, a behavior known as thigmotaxis. This behaviour can trigger smoke detectors and fire alarms and thus cause considerable inconvenience. Similarly, thrips can invade computers, watches, paintings, polystyrene building insulation, hypodermic needles in manufacture, and many other unlikely places (Hoddle et al. 2008). Thrips may also become a nuisance when they swarm and land on exposed areas of skin but humans

[1] Not all plant feeding by thrips is disadvantageous: attempts have been made in USA to control alligator weed (*Alternanthera philoxeroides*) by *Amynothrips andersoni* imported from Argentina.

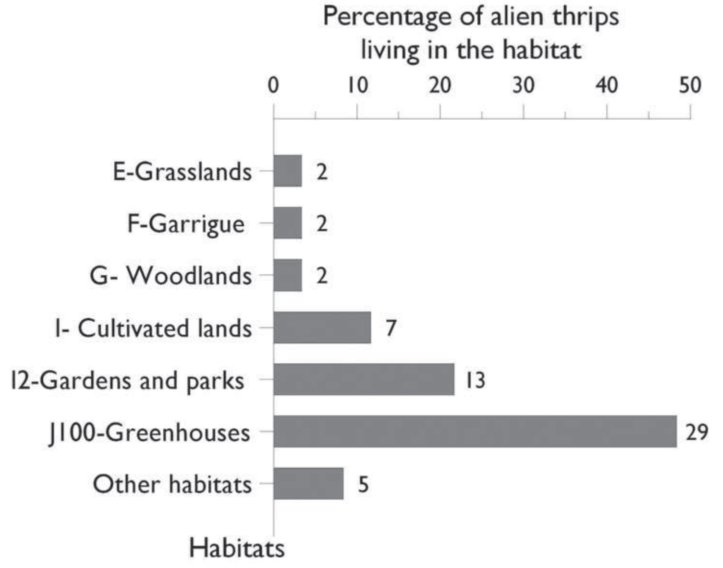

Figure 13.1.6. Main European habitats colonized by the established alien species of Thysanoptera. The number over each bar indicates the absolute number of alien thrips recorded per habitat. Note that a species may have colonized several habitats.

are usually unintended, occasional, short-term hosts without medical consequences (Faulde et al. 2007).

Throughout the world, only six of the 210 described species of *Frankliniella* are known to be vectors of viruses, only four of the 290 species of the genus *Thrips*, and just one of the 100 species of *Scirtothrips*. In addition, one species of *Ceratothripoides* and *Microcephalothrips abdominalis* are known to transmit virus. Thrips transmit plant viruses in the *Tospovirus, Ilarvirus, Carmovirus, Sobemovirus* and *Machlomovirus* genera (Jones 2005).

Of over 52 species of alien thrips, less than 10 can be considered as having an impact on human activities. The ecology and biology of other species is generally poorly known and ecological and economic impact cannot be evaluated. Various members of the genus *Franklinothrips* are of economic importance (Mound and Reynaud 2005). *F. vespiformis* is recently marketed in continental Europe and Israel as a biocontrol agents in greenhouses for the control of thrips and mite pests; its prey also includes whiteflies and leafminers (Larentzaki et al. 2007).

Frankliniella occidentalis (the Western flower thrips) is a major worldwide crop pest with a huge economic impact and has become a key pest in a large range of agricultural and floricultural production areas in the world (see factsheet 14.78). It has a very extensive host range including field crops, orchards, greenhouse crops and weeds. The Western flower thrips is considered as the most important thrips vector of diseases. It transmits *Chrysanthemum stem necrosis virus* (CSNV), *Groundnut ringspot virus* (GRSV), *Impatiens necrotic spot virus* (INSV), *Tomato chlorotic spot virus* (TCSV) and *Tomato*

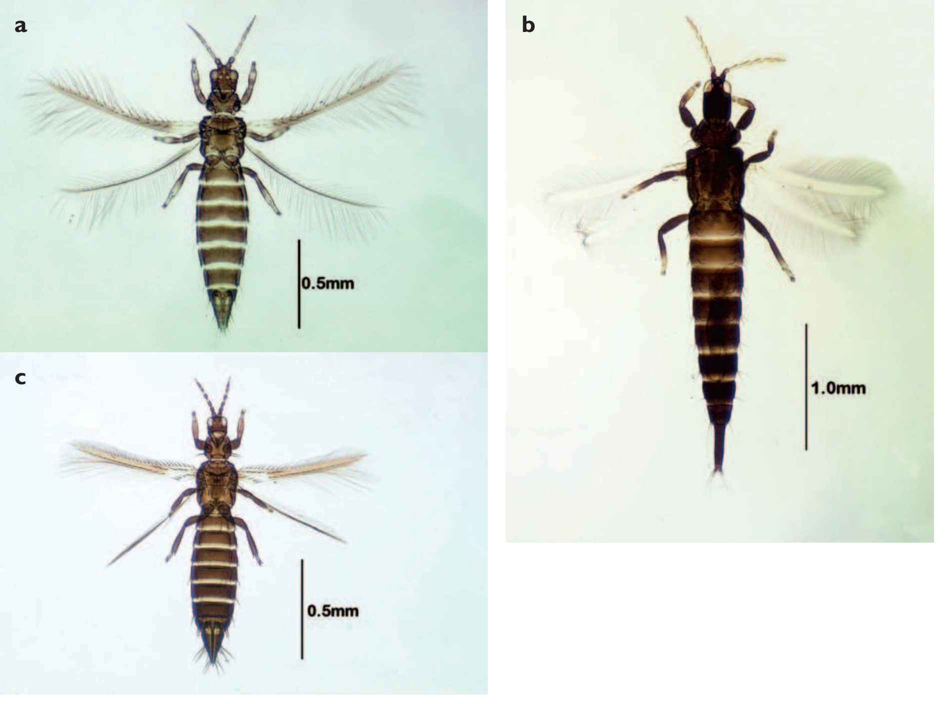

Figure 13.1.7. Adults of some Thysanoptera alien *to* Europe. **a** *Echinothrips americanus* **b** *Gynaikothrips ficorum* **c** *Pezothrips kellyanus* (credit: Philippe Reynaud, LNPV).

spotted wilt virus (TSWV). There is also an indirect economic effect when introduced into a new area. For example, western flower thrips is a major economic driving force of greenhouse and field crop IPM research. *F. occidentalis* is restricted to glasshouses in northern Europe, but has established outdoors in areas with milder winters. The international spread of the western flower thrips occurred predominantly by the movement of horticultural material, such as cuttings, seedlings and potted plants. Within Europe, an outward spread from the original outbreak in the Netherlands (1983) is discernible. The speed of spread was 229 +/- 20 km/year (Kirk and Terry 2003). Chemical control is difficult, because *F. occidentalis* is resistant to most pesticides, but some predatory mites and minute Pirate bugs provide effective biological control under glasshouses. Two other North American *Frankliniella* species are known in Europe, but with a very limited distribution and without economic impact. The potential introduction of the Melon thrips (*Thrips palmi*) represents a continuous threat to glasshouse ornamental and vegetable crops in Europe (see factsheet 14.80). Numerous interceptions have been reported on cut flowers and fruit vegetables and several outbreaks were found in glasshouses in the Netherlands and UK since 1988. The potential of adults and larvae to survive an entire winter oudoors in the UK is very limited however (McDonald et al. 2000), which has favoured successful control and eradication of all these outbreaks. *T. palmi* is considered to be absent in Europe, although it was detected outdoors within flowers of kiwi fruit (*Actinidia deliciosa*) in Portugal in 2004, but in later surveys the pest was no longer found. The palm thrips is essentially a tropical species, and therefore most parts of Europe are not suitable for its establishment. We can assume, however, that most of southern Europe could harbour this species outdoors and the species could establish indoors in other places. High developmental and reproductive rates at glasshouse temperatures allows rapid build-up of populations, even from small numbers of females (Cannon et al. 2007). Vector of alien topospovirus, the Melon thrips has been implicated in the transmission of at least six plant viruses. *T. palmi* is a quarantine organism for the EU and as such requires eradication wherever it is found.

Several other alien thrips species occur indoor in Europe with a low economic impact, including *Hercinothrips femoralis*, *Heliothrips haemorrhoidalis* and *Echinothrips americanus*. These species are found in the wild in tropical and subtropical regions, but are restricted to glasshouses in western Europe, with the exception of *H. haemorrhoidalis* (also called the greenhouse thrips). The greenhouse thrips can also live in the wild in southern Europe. It has many hosts, including ornamental shrubs and field crops (citrus, avocado and tea) but preferred hosts in Southern Europe are *Myrtus communis* and *Viburnum tinus*. *E. americanus* was recently introduced from the USA, where it is seldom a pest, into Europe (Netherlands). However, in Europe it has more than 50 known food plants, including ornamental and woody plants and vegetables. The species is often found in sizable numbers without showing obvious damage symptoms to the plant (Vierbergen et al. 2006) and seems to be highly susceptible to insecticides (Karadjova and Krumov 2003). *H. femoralis* (the sugar beet thrips) is a minor polyphagous pest under glasshouses that feeds on more than 50 hostplants but is also an important pest almost everywhere where bananas are grown (Trdan et al. 2007).

The genus *Gynaikothrips* includes about 40 species, with two related pest species (*G. ficorum* and *G. uzeli*). The same common name (Cuban Laurel Thrips) is used for these two leaf-galling thrips species on decorative *Ficus* trees distributed worldwide by the horticultural trade. But only *Gynaikothrips ficorum* is at the present time known as an alien species in Europe. These two species can only be differenciated by a microscopic examination of the pronotal posteroangular pair of setae. According to Mound et al. (Mound et al. 1995), *G. ficorum* is the primary gall maker on *Ficus microcarpa* while *G. uzeli* is the primary gall maker on *F. benjamina*. *G. ficorum* was first described from Algeria, but is native of Southeast Asia. Adults vary from about 2.6 mm to 3.6 mm in length and are dark yellowish-brown to black. Infested, curled leaves become hard and tough, then gradually yellower and browner and eventually drop from the plant prematurely. Finally, the ornamental value of the plant is reduced. The Cuban Laurel Thrips is a minor pest in Europe and only under glasshouses, but adults can be a nuisance in North Africa on *Ficus microcarpa* planted in cities, by flying into people's eyes or irritating their skin (Mumcuoglu and Volman 1988).

The Composite thrips *Microcephalothrips abdominalis*, the only species in the genus, is a light-brown species characterized by an unusual small head in relation to the pronotum. It lives on Compositae flowers throughout its life, where it is considered as an important pollinating agent. *M. abdominalis* is known to transmit TSV (Greber et al. 1991), a serious disease of peanut and sunflower in India (Jones 2005) but this virus is not a quarantine pest for EU. It has been suggested that this pantropical species is native to the New World and has been transported elsewhere by man (Stannard 1968). This species has been known from Italy since 1994 but has subsequently shown a slow rate of spead in Europe. The Composite thrips is considered as a minor pest but is not reported yet as a pest in Europe.

References

Aitkenhead P (1951) The Gladiolus Thrips - a Pest new to Britain. *Agriculture* 57, 11: 517–523.

Anonymous (2004) First report of *Thrips palmi* in Portugal. *EPPO Reporting Service* 144: 2.

Bagnall RS (1909) On the Thysanoptera of the Botanical Gardens, Brussels. *Annales de la Société entomologique de Belgique* 53: 171–176.

Bagnall RS (1911) Descriptions of three new Scandinavian Thysanoptera (Tubulifera). *Entomologist's Monthly Magazine* 47: 60–63.

Bagnall RS (1913) Further notes on new and rare British Thysanoptera (Terebrantia) with descriptions of new species. *Journal of economic Biology* 8: 231–240.

Bagnall RS (1919) Brief descriptions of new Thysanoptera, X. *The Annales and Magazine of Natural History* 4, 9: 253–277.

Bagnall RS (1923) A contribution towards a knowledge of the British Thysanoptera, with description of new species. *Entomologist's Monthly Magazine* 59: 57–60.

Bagnall RS (1933) More new and little-known British thrips. *Entomologist's Monthly Magazine* 69: 120–123.

Bagnall RS, John O (1935) On some Thysanoptera collected in France. *Annales de la Société Entomologique de France.* 104: 307–327.

Berzosa J (1988) *Karnyothrips americanus* (Hood, 1912) in the Iberian Peninsula (Thysanoptera, Phalaeothripidae). *Boletin de la Asociacion Espanola de Entomologia* 12: 137–141.

Berzosa J, Arnaldos MI, Romera E, García MD (2001) Tisanópteros (Insecta: Thysanoptera) de una comunidad sarcosa-prófaga en el sureste español. *Boletín de la Real Sociedad Española de Historia Natural (Sección Biológica)* 96, 3/4: 183–194.

Billen W, Zur-Strassen R (1995) Zwei tropische Thripiden-Arten (Insecta: Thysanoptera) an aus Java importiertem Wasserfarn in Deutschland. *Mitteilungen der Entomologischen Gesellschaft Basel* 45, 3: 154–159.

Blank RH, Gill GSC (1997) Thrips (Thysanoptera: Terebrantia) on flowers and fruit of citrus in New Zealand. *New Zealand Journal of Crop and Horticultural Science* 25: 319–332.

Bouché PF (1833) *Naturgeschichte der schädlichen und nützlichen Garten-Insekten und die bewähtesten Mittel zur Vertilgung der ersteren*. Berlin: Nicolai. 176pp.

Bournier A (1954) Le thrips du glaïeul *Taeniothrips simplex* Morison. *Phytoma* 58: 10–13.

Bournier A (1960) Espèces nouvelles dans la faune thysanoptérologique des litières de feuilles de chêne vert (*Quercus ilex* L.). *Vie et Milieu* 11: 88–101.

Bournier A (1983) *Les thrips: Biologie. Importance agronomique*. Paris: Institut National de la Recherche Agronomique. 128pp.

Canale A, Conti B, Petacchi R, Rizzi I (2003) Thysanoptera collected in an olive-growing area of the northern Tuscany (Italy). *Entomological Problems* 33, 1–2: 105–110.

Cannon RJC, Matthews L, Collins DW, Agallou E, Bartlett PW, Walters KFA, MacLeod A, Slawson DD, Gaunt A (2007) Eradication of an invasive alien pest, *Thrips palmi*. *Crop Protection* 26: 1303–1314.

Cappellozza L, Miotto F (1975) *Pseudodendrothrips mori* (Niwa) (Thysanoptera Terebrantia) specie nuova per la fauna Italiana. *Redia* 56: 387–389.

Colombo M, Rigamonti IE, Eordegh FR (1999) Segnalazione di *Bradinothrips musae* (Hood) (Thysanoptera Thripidae) in una serra della Lombardia. *Bollettino di Zoologia Agraria e di Bachicoltura* 31, 2: 231–234.

Del Bene G, Gargani E (2001) *Chaetanaphothrips orchidii* (Moulton) (Thysanoptera Thripidae): a thrips new to Italy. *Redia* 84: 119–128.

Faulde MK, Sorhage B, Ksoll A, Tisch M (2007) Human *Limothrips cerealium* infestation associated with onychomycosis. *Journal of the European Academy of Dermatology and Venerology* 21: 841–843.

Geiter O, Homma S, Kinzelbach R (2002) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltbundesamt 25: 1–173.

Greber RS, Klose MJ, Teakle DS (1991) High incidence of Tobacco streak virus in tobacco and its transmission by *Microcephalothrips abdominalis* and pollen from *Ageratum houstonianum*. *Plant Disease* 75: 450–452.

Heeger E (1854) Beiträge zur Naturgeschichte der Insekten Osterreichs. *Sitzungsberichte der Akademie der Wissenschaften in Wien. Mathematisch-Naturwissenschaftliche Klasse* 14: 365–373.

Hoddle MS, Mound LA (2003) The genus *Scirtothrips* in Australia (Insecta, Thysanoptera, Thripidae). *Zootaxa* 268: 1–40.

Hoddle MS, Mound LA, Nakahara S (2004) Thysanoptera recorded from California, U.S.A.: a checklist. *Florida Entomologist* 87: 317–323.

Hoddle MS, Mound LA, Paris DL (2008) Thrips of California. CBIT Publishing, Queensland. http://keys.lucidcentral.org/keys/v3/thrips_of_california/Thrips_of_California.html.

Jenser G (1989) Thysanoptera species, new to the fauna of Hungary. [Hungarian]. *Folia Entomologica Hungarica* 50: 169–170.

Jones DR (2005) Plant viruses transmitted by thrips. *European Journal of Plant Pathology* 113, 2: 119–157.

Karadjova O, Krumov V (2003) *Echinothrips americanus* Morgan (Thysanoptera: Thripidae), a new pest of the Bulgarian greenhouses. *Proceedings of the International Scientific Conference "50 years University of Forestry"*, Sofia (Bulgaria), April 2003, 122–125.

Kirk WDJ, Terry LI (2003) The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). *Agricultural And Forest Entomology* 5: 301–310.

Kobro S, Rafoss T (2006) Identification of adult males and females of *Hoplothrips* species (Thysanoptera: Tubulifera) known from Norway, and some deductions on their life history. *Entomologica Fennica* 17, 2: 184–192.

Kucharczyk H, Zawirska I (2001) On the occurrence of Thysanoptera in Poland. In Mound LA, Marullo R (Eds) *Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera*. Reggio Calabria, Italy: CSIRO Entomology, 341–344.

Larentzaki E, Powell G, Copland MJW (2007) Effect of temperature on development, overwintering and establishment potential of *Franklinothrips vespiformis* in the UK. *Entomologia Experimentalis et Applicata* 124: 143–151.

Laudonia S, Viggiani G (2005) Extensive infestations by a thrips on figs in Campania. *Informatore Agrario* 61, 20: 73–74.

Lewis T (Ed) (1997) *Thrips as Crop Pests*. Wellingford, Oxon, UK, New York, USA: CAB International. 349 pp.

Mantel WP, van de Vrie M (1988) A contribution to the knowledge of Thysanoptera in ornamental and bulbous crops in the Netherlands. *Acta Phytopathologica et Entomologica Hungarica.* 23: 301–311.

McDonald JR, Head J, Bale JS, Walters KFA (2000) Cold tolerance, overwintering and establishment potential of *Thrips palmi*. *Physiological Entomology* 25: 159–166.

Milevoj L, Zdešar M, Trdan S (2008) Susceptibility to gladiolus thrips (*Thrips simplex* [Morison]) in four different coloured gladiolus cultivars. *Acta Phytopathologica et Entomologica Hungarica* 43, 2: 323–327.

Morse MS, Hoddle MS (2006) Invasion biology of thrips. *Annual Review of Entomology* 51: 67–89.

Mound LA (1974) The *Nesothrips* complex of spore-feeding Thysanoptera (Phlaeothripidae: Idolothripinae). *Bulletin of the British Museum (Natural History)* 31: 107–188.

Mound LA (1976) Thysanoptera of the genus *Dichromothrips* on old world Orchidaceae. *Biological Journal of the Linnean Society* 8: 245–265.

Mound LA (1983) Natural and disrupted patterns of geographical distribution in Thysanoptera (Insecta). *Journal of Biogeography* 10: 119–133.

Mound LA, (1999) Saltatorial leaf-feeding Thysanoptera (Thripidae: Dendrothripinae) from Australia and New Caledonia, with newly recorded pests of ferns, figs and mulberries. *Australian Journal of Entomology* 38: 257–273.

Mound LA (2000) The aquatic thrips *Organothrips indicus* Bhatti (Thysanoptera: Thripidae) in Queensland, and a new species, *O. wrighti*, from tropical Australia. *Australian Journal of Entomology* 39: 10–14.

Mound LA (2002) So many thrips - so few tospoviruses. In Mound LA, Marullo R (Eds) *Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera*. Reggio Calabria, Italy: CSIRO Entomology, 15–18.

Mound LA (2006) Vicariance or dispersal - Trans-Tasman faunal relationships among Thysanoptera (Insecta), with a second species of *Lomatothrips* from *Podocarpus*. *Papers and Proceedings of the Royal Society of Tasmania* 140: 11–15.

Mound LA (2007) Thysanoptera (Thrips) of the World – a checklist. http://www.ento.csiro.au/thysanoptera/worldthrips.html.

Mound LA, Marullo R (1994) New thrips on mother-in-law's tongue. *Entomologist's Monthly Magazine* 130, 1560–1563: 95–98.

Mound L.A, Marullo R (1996) The thrips of central and south America: an introduction (Insecta: Thysanoptera). *Memoirs on Entomology, International* 6: 1–488.

Mound LA, Morison GD, Pitkin BR, Palmer JM (1976) Thysanoptera. *Handbooks for the identification of British Insects*. London: Royal Entomological Society 1/11. 82 pp.

Mound LA, Morris DC (2007) The insect Order Thysanoptera: Classification versus Systematics. *Zootaxa* 1668: 395–411.

Mound LA, Reynaud P (2005) *Franklinothrips*, a pantropical Thysanoptera genus of ant-mimicking obligate predators (Aeolothripidae). *Zootaxa* 864: 1–16.

Mound LA, Teulon DAJ (1995) *Thysanoptera as phytophagous opportunists*. In Parker BL, Skinner M, Lewis T. Thrips Biology and Management. New York: Plenum, 3–20.

Mound LA, Wang C, Okajima S (1995) Observations in Taiwan on the identity of the Cuban laurel thrips (Thysanoptera, Phlaeothripidae). *Journal of the New York Entomological Society* 103: 185–190.

Mumcuoglu KY, Volman Y (1988) Thrips stings in Israel: a case report. *Israel Journal of Medical Sciences* 24: 715.

Palmer JM, Mound LA (1985) New World Thripidae (Thysanoptera) with nine-segmented antennae. *Zoological Journal of the Linnean Society* 84: 181–194.

Pelikán J (1990) Faunistic records from Czechoslovakia. Thysanoptera. *Acta Entomologica Bohemoslovaca* 87: 232–234.

Pelikán J (1991) The Cuban-laurel thrips (*Gynaikothrips ficorum* Marchal, 1908) in greenhouses in Czechoslovakia. [Czech]. *Ochrana Rostlin* 27: 287–291.

Pelikán J, Schliephake G (1994) Eine neue bemerkenswerte *Apterygothrips*- Art aus Mitteleuropa (Thysanoptera: Phlaeothripidae). *Entomologische Zeitschrift* 104: 181–185.

Perrings C, Dehnen-Schmutz K, Touza J, Williamson M (2005) How to manage biological invasions under globalization. *Trends in Ecology and, Evolution* 20: 212–215.

Pitkin BR (1972) A Revision of the flower-living genus *Odontothrips* Amyot et Serville (Thysanoptera: Thripidae). *Bulletin of the British Museum (Natural History) Entomology* 26: 373–402.

Priesner H (1919) Zur Thysanopteren-Fauna Albaniens. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften* 128: 115–144.

Priesner H (1964a) A monograph of the Thysanoptera of the Egyptian deserts. *Publications de l'Institut du Désert d'Egypte* 13: 1–549.

Priesner H (1964b) Ordnung Thysanoptera (Fransenflügler, Thripse). In Franz H., *Bestimmungsbücher zur Bodenfauna Europas* 2. Berlin: Akademie Verlag, 1–142.

Reuter OM (1891) Thysanoptera funna i finska orangerier. *Meddelanden af Societatis pro Fauna et Flora Fennica* 17: 161–167.

Reuter OM (1904) Ein neues Warmhaus-Thysanopteron. *Meddelanden af Societatis pro Fauna et Flora Fennica* 30: 106–109.

Reynaud P (1998) *Echinothrips americanus*. Un nouveau thrips des serres importé en France. *Phytoma* 507: 36–38.

Reynaud P, Bertaux F, Martinez M (2001) Premier signalement en Europe de *Neohydatothrips samayunkur* (Kudo) (Thysanoptera, Thripidae). *Nouvelle Revue d'Entomologie* 18: 91–93.

Sakimura K (1967) Redescription of *Anaphothrips orchidaceus* and *A. orchidearum* (Thysanoptera: Thripidae). *The Florida Entomologist* 50: 89–97.

Stannard LJ (1968) The Thrips, or Thysanoptera, of Illinois. *Bulletin of the Illinois Natural History Survey* 29: 213–552.

Strapazzon A (1999) Italian faunal records 368. *Bollettino Della Societa Entomologica Italiana* 131: 259.

Streito JC, Martinez M (2005) Nouveaux ravageurs, 41 espèces depuis 2000. *Phytoma - La défense des Végétaux* 586: 16–20.

Trdan S, Jovic M, Andjus L (2005) Palm thrips, *Parthenothrips dracaenae* (Heeger) (Thysanoptera: Thripidae), in Slovenia: still a pest of minor importance? *Acta agriculturae Slovenica* 85: 211–217.

Trdan S, Kuznik L, Vidrih M (2007) First results concerning the efficacy of entomopathogenic nematodes against *Hercinothrips femoralis* (Reuter). *Acta Agriculturae Slovenica* 89: 5–13.

Varga L (2008) *Hercinothrips femoralis* (Reuter, 1891) – a new pest thrips (Thysanoptera: Panchaetothripinae) in Slovakia. *Plant Protection Science* 44: 114–118.

Vierbergen G, Mantel WP (1991) Contribution to the knowledge of *Frankliniella schultzei* (Thysanoptera: Thripidae). *Entomologische Berichten* 51: 7–12.

Vierbergen G (1996) *Annual Report 1996*. Wageningen, Netherlands: Plant Protection Service, Diagnostic Centre. 114 pp.

Vierbergen G (1998) *Echinothrips americanus* Morgan, a new thrips in Dutch greenhouses (Thysanoptera: Thripidae). *Proceedings of the section Experimental and Applied Entomology of the Netherlands Entomological Society (N.E.V.)* 9: 155–160.

Vierbergen G (2004) Eight species of thrips new for the Netherlands and some taxonomical changes in *Stenchaetothrips*, *Thrips* and *Hoplothrips* (Thysanoptera). *Acta Phytopathologica et Entomologica Hungarica* 39: 199–209.

Vierbergen G, Cean M, Szeller IH, Jenser G, Masten T, Simala M (2006) Spread of two thrips pests in Europe: *Echinothrips americanus* and *Microcephalothrips abdominalis* (Thysanoptera: Thripidae). *Acta Phytopathologica et Entomologica Hungarica* 41: 287–296.

Webster KW, Cooper P, Mound LA (2006) Studies on Kelly's citrus thrips, *Pezothrips kellyanus* (Bagnall) (Thysanoptera: Thripidae): sex attractants, host associations and country of origin. *Australian Journal of Entomology* 45, 1: 67–74.

Wilson TH (1975) A monograph of the subfamily Panchaetothripinae (Thysanoptera: Thripidae). *Memoirs of the American Entomological Institute* 23: 1–354.

Zur-Strassen R (1965) Einige neue terebrante Thysanopteren-Arten von den Kanarischen Inseln (Ins., Thysanoptera). *Commmentationes biologicae Societas scientiarus fennica* 28: 3–41.

Zur-Strassen R (1973a) Ergebnisse der Forschungsreise auf die Azoren 1969. III Zur Faunistik und Zoogeographie der Thysanopterenfauna der Azoren im Mittel-Atlantik. *Boletin do Museo Municipal do Funchal* 27, 117: 26–50.

Zur-Strassen R (1973b) Uber einige zumeist floricole Fransenfluger ans dem sudlichen Andalusien (Spaniena) (Ins Thysanoptera). *Senckenbergiana biologia* 54: 327–338.

Zur-Strassen R (1982) Thysanopterologische Notizen (6) (Insecta: Thysanoptera). *Senckenbergiana Biologica* 63: 191–209.

Zur-Strassen R (1986a) *Frankliniella occidentalis* (Pergande 1985), ein nordamerikanischer Fransenflügler (Thysanoptera) als neuer Bewohner europäischer Gewächshäuser. *Nachrichtenblatt Deutschen Pflanzenschutzdienstes* 38: 86–88.

Zur-Strassen R (1986b). Thysanopteran auf Inseln der Nordlichen Sporaden in der Agais (Griechenland). *Senckenbergiana Biologica* 67: 85–129.

Zur-Strassen R (1995) *Dorcadothrips billeni* n. sp. (Insecta: Thysanoptera), ein neuer terebranter Fransenflugler von Wasserfarn. *Mitteilungen der Entomologischen Gesellschaft Basel* 45: 148–153.

Zur-Strassen R (1996) New data on systematics and distribution of some West Palaearctic Terebrantia species (Thysanoptera). *Entomologische Nachrichten Und Berichte* 40: 111–118.

Zur-Strassen R (2003) *Die terebranten Thysanopteren Europas und des Mittelmeer-Gebietes. Die Tierwelt Deutschlands 74*. Keltern, Germany: Verlag Goecke and Evers. 277 pp.

Zur-Strassen R, Borges PAV (2005) Thysanoptera. In: Borges PAV, Cunha R, Gabriel R, Martins AMF, Silva L, Vieira V (Eds) *A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Horta, Angra do Heroísmo and Ponta Delgada: Direcção Regional de Ambiente e do Mar dos Açores and Universidade dos Açores, 189–190.

Table 13.1.1. List and main characteristics of the Thysanoptera species alien *to* Europe. Status: A: Alien *to* Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 03/02/2010.

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Aeolothripidae								
Franklinothrips megalops (Trybom, 1912)	A	predator	Africa	Unknown	BG, ES, NL	J100	Greenhouses thrips and black vine thrips	Zur-Strassen (2003), Mound and Reynaud (2005)
Franklinothrips vespiformis (Crawford, 1909)	A	predator	C & S America	Unknown	BE, CH, DE, DK, FR, IL, NL, PT-MAD, SE	J100	*Frankliniella occidentalis* and two- spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae).	Zur-Strassen (2003)
Merothripidae								
Merothrips floridensis Watson, 1927	A	detrito-vorous	C & S America	1955, FR	ES, FR, PT-AZO	I	*Citrus* (fungivorous)	Bournier (1960), Zur-Strassen and Borges (2005)
Phlaeothripidae								
Aleurodothrips fasciapennis (Franklin, 1908)	C	predator	Crypto-genic	1908, BE	BE, DE	J100	*Aonidella, Crysomphalus* and other scales	Bagnall (1909), Geiter et al. (2002)
Bagnalliella yuccae (Hinds, 1902)	A	phyto-phagous	North America	1957, FR	FR, HU, IT, RO, UA	I2	*Yucca*	Jenser (1989)
Eurythrips tristis Hood, 1941	A	unknown	North America	2005, PT-AZO	PT- AZO	U	Sporophagous	Zur-Strassen and Borges (2005)
Gynaikothrips ficorum (Marchal, 1908)	A	phyto-phagous	Asia-Tropical	1983, FR-COR	CZ, DE, FR-COR, GR-CRE, IL, IT, IT- SAR, IT- SIC, NL, PT, PT-MAD	I2, J100	*Ficus*	Bournier (1983), Pelikán (1991), Laudonia and Viggiani (2005)
Haplothrips gowdeyi (Franklin, 1908)	A	phyto-phagous	Africa	1978, GR	CY, ES, ES- CAN, GR, PT-AZO, PT-MAD	I	Solenaceae, Apiaceae	Zur-Strassen (1986b), Zur-Strassen and Borges (2005)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Haplothrips rivnayi Priesner, 1936	A	phyto-phagous	Asia	2001, ES	ES	I2	*Crataegus oxyacantha*	Berzosa et al. (2001)
Hoplothrips lichenis Knechel, 1954	C	detrito-vorous	Crypto-genic	1954, RO	CZ, RO	G	*Prunus armeniacum*	Pelikán (1990)
Hoplothrips unicolor (Vuillet, 1914)	C	detrito-vorous	Crypto-genic	1939, GB	CZ, GB, NO, SE	X16	*Polystictus abietinus* fungus on dead pine branches	Kobro and Rafoss (2006), Mound et al. (1976)
Karnyothrips americanus (Hood, 1912)	A	predator	North America	1974, ES	ES	X13	Predator (sparsely wooded land)	Berzosa (1988)
Karnyothrips flavipes (Jones, 1912)	A	predator	North America	1919, AL	AL, CY, ES, IT- SAR, PT	I2	*Fiorinia fioriniae* (scale) on many ornamentals	Priesner (1919), Canale et al. (2003)
Karnyothrips melaleucus (Bagnall, 1911)	A	predator	C & S America	1911, DK	DK, ES- CAN, IT, PT-AZO, PT-MAD,	J100	Coccidae, Diaspididae scales (*Howardia biclavis*)	Bagnall (1911), Mound and Marullo (1994), Zur-Strassen and Borges (2005)
Nesothrips propinquus (Bagnall, 1916)	A	detrito-vorous	Australasia	1974, PT-AZO	ES- CAN, NL, PT-AZO, PT-MAD	I	Sporophagous	Mound (1974), Zur-Strassen and Borges (2005)
Podothrips semiflavus Hood, 1913	A	parasitic/ predator	North America	1964, CY	CY	I	*Aspidiella sacchari* (coccid scale)	Priesner (1964b)
Suocerathrips linguis Mound & Marullo, 1994	C	detrito-vorous	Crypto-genic	1994, GB	BE, GB	J100	*Penicilium* species living on *Sansevieria* surface	Mound and Marullo (1994)
Thripidae								
Anaphothrips sudanensis Trybom, 1911	A	phyto-phagous	Tropical, sub-tropical	Unknown	ES, CY	E1, F6	Grasses, cereals	Zur-Strassen (2003)
Anisopilothrips venustulus (Priesner, 1923)	A	phyto-phagous	C & S America	1969, P-AZO	IT, PT-AZO, PT-MAD	I	*Cyathula prostrata* (folivorous) and young coconut fruits	Zur-Strassen (1973a), Zur-Strassen and Borges (2005)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Aurantothrips orchidaceus (Bagnall, 1909)	A	phyto-phagous	C & S America	1907, GB	BE, DE, DK, FR, GB, NO, SE	J100	Orchidaceae	Bagnall and John (1935), Sakimura (1967)
Bradinothrips musae Hood, 1956	A	phyto-phagous	C & S America	1998, I	IT, SE	J100	*Spathiphyllum*	Colombo et al. (1999)
Caliothrips fasciatus (Pergande, 1895)	A	phyto-phagous	North America	Unknown, GB	GB	J100	Navel oranges exports (contaminant)	Zur-Strassen (2003)
Chaetanaphothrips orchidii (Moulton, 1908)	A	phyto-phagous	C & S America	1935, F	BE, CZ, DE, DK, FI, FR, GB, IL, IT, NO, NL, PT-MAD, SE	J100	*Anthurium*, banana, *Citrus*, orchids	Bagnall and John (1935), Del Bene and Gargani (2001)
Copidothrips octarticulatus (Schmutz, 1913)	A	phyto-phagous	Asia-Tropical	1996, NL	IT, NL	J100	Araceae, *Piper*	Vierbergen (1996)
Dichromothrips corbetti (Priesner, 1936)	A	phyto-phagous	Asia-Tropical	Unknown, NL	NL	J100	Orchidaceae (*Vanda*)	Mantel and van de Vrie (1988)
Dichromothrips phalaenopsidis Sakimura, 1955	A	phyto-phagous	Asia-Tropical	1975, NL	NL	J100	Orchidaceae	Mound (1976)
Dorcadothrips billeni Zur-Strassen, 1995	A	phyto-phagous	Asia-Tropical	1994, DE	DE	J100	*Microsorum pteropus* (Oriental water fern)	Zur-Strassen (1995)
Echinothrips americanus Morgan, 1913	A	phyto-phagous	North America	1996, FR	AT, BE, BG, DE, DK, FR, FR-COR, GB, IT, NL, NO, SE, SI	J100	*Hibiscus* (but polyphagous on ornemental crops)	Reynaud (1998), Vierbergen (1998), Vierbergen et al. (2006), Zur-Strassen (2003)
Frankliniella schultzei (Trybom, 1910)	C	phyto-phagous	Crypto-genic	1988, NL	NL	J100	Polyphagous, recorded as a pest of vegetables and ornemental crops	Vierbergen and Mantel (1991)
Frankliniella fusca (Hinds, 1902)	A	phyto-phagous	North America	1964, NL	NL	J100	Polyphagous, reported to cause direct damage to peanuts and cotton	Mantel and van de Vrie (1988)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Frankliniella occidentalis (Pergande, 1895)	A	phyto-phagous	North America	1983, NL	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IL, IT, IT-SAR, IT-SIC, LT, LV, NL, NO, PT, RO, RS, SE, SK, SI, UA	I2, J100	Polyphagous (Plants, trees- *Populus*); flowers and leaves; vector tobacco streak ilarvirus (TSV) and tomato spotted wilt virus (TSWV)	Zur-Strassen (1986a), Kirk and Terry (2003)
Heliothrips haemorrhoidalis (Bouché, 1833)	A	phyto-phagous	C & S America	1833, DE	AL, AT, BE, BG, CH, CZ, DE, DK, ES, FI, FR, FR- COR, GB, GR, HU, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, MT, NL, NO, PT, PT-AZO, PT-MAD, RO, SE, SI, SK, UA	I2, J100	Polyphagous (*Citrus*, avocados, ornamental plants) in urban , agricultural and modified habitats, rarely forests, mainly greenhouses	Bouché (1833), Mound et al. (1976), Zur-Strassen (2003), Zur-Strassen and Borges (2005)
Hercinothrips bicinctus (Bagnall, 1919)	A	phyto-phagous	Tropical, sub-tropical	1907, BE	BE, DE, DK, ES, ES-CAN, FR, GB, HU, IT, NL, PT-AZO, PT-MAD	J100	*Musa* spp., passionfruit (folivorous)	Bagnall (1919), Mound et al. (1976), Wilson (1975), Zur-Strassen and Borges (2005)
Hercinothrips femoralis (Reuter, 1891)	A	phyto-phagous	C & S America	1891, FI	BE, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, HU, IL, IT, LV, MD, NL, RO, SE, SK, SI, UA	J100	Polyphagous (banana, beet, celery, *Commelina diffusa*, Crinum, Chrysanthemum, dwarf milo maize, eggplant, *Emilia sonchifolia*, *Erechtites hieracifolia*, grass, orchids, pineapple, *Plantago major*)	Reuter (1891), Mound et al. (1976), Varga (2008)
Leucothrips nigripennis Reuter, 1904	A	phyto-phagous	C & S America	1904, FI	AL, BE, CZ, DE, DK, FI, FR, GB, NL	J100	Ferns	Reuter (1904), Mound (1999)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Microcephalothrips abdominalis (Crawford, 1910)	A	phyto-phagous	Tropical, sub-tropical	1999, IT	ES-CAN, HU, IT, SI	I2	Asteraceae (*Bidens formosa* -cosmos, *Chrysanthemum, Helianthus, Pyrethrum, Tagetes, Zinnia*)	Strapazzon (1999), Vierbergen et al. (2006)
Neohydatothrips samayunkur (Kudo, 1995)	A	phyto-phagous	Tropical, sub-tropical	2000, FR	FR	I	Marigold (*Tagetes* sp.)	Reynaud et al. (2001)
Organothrips indicus Bhatti, 1974	A	phyto-phagous	Asia	1985, DE	DE	J100	Water hyacinth (*Eichhornia crassipes*) in warmed aquarium (aquatic species)	Mound (2000)
Palmiothrips palmae (Ramakrishna, 1934)	A	phyto-phagous	Asia-Tropical	1965, ES-CAN	ES-CAN, IL	I2	*Phoenix* flowers, including date palm, *Phoenix dactilifera*	Zur-Strassen (1965)
Parthenothrips dracaenae (Heeger, 1854)	A	phyto-phagous	Africa	1852, AT	AT, BE, BG, CH, CZ, DE, DK, ES, FI, FR, GB, GR, HU, IS, IT, LV, MD, NL, NO, RO, SE, SI	J100	*Dracena, Ficus*	Heeger (1854), Trdan et al. (2005)
Pezothrips kellyanus (Bagnall, 1916)	C	phyto-phagous	Crypto-genic	1981, GR	ES, FR, GR, IT-SIC, IL, NL	I2	*Citrus*	Zur-Strassen (1986b), Zur-Strassen (2003)
Phibalothrips peringueyi (Faure, 1925)	A	phyto-phagous	Tropical, sub-tropical	1985, IT-SIC	IT, IT-SIC	E	Grasses	Zur-Strassen (1996), Zur-Strassen (2003)
Plesiothrips perplexus (Beach, 1896)	A	phyto-phagous	C & S America	1975, PT-MAD	IT, PT-AZO, PT-MAD	E	Poaceae	Zur-Strassen (1982), Zur-Strassen and Borges (2005)
Pseudodendrothrips mori (Niwa, 1908)	A	phyto-phagous	Asia-Tropical	1974, IT	ES, FR, IT, SI	I2	*Morus*	Cappellozza and Miotto (1975), Vierbergen et al. (2006)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Psydrothrips kewi Palmer & Mound, 1985	A	phyto-phagous	C & S America	1982, GB	GB	J100	*Philodendron*	Palmer and Mound (1985)
Pteridothrips pteridicola (Karny, 1914)	A	phyto-phagous	Asia-Tropical	1995, DE	DE, SE	J100	*Microsorum pteropus* (Oriental water fern)	Billen and Zur-Strassen (1995)
Scirtothrips longipennis (Bagnall, 1909)	C	phyto-phagous	Crypto-genic	1909, BE	BE, CZ, DE, DK, FI, FR, IT, LV, NO, NL, PT-MAD, SE	J100	Avocado, onions, …	Bagnall (1909), Hoddle and Mound (2003)
Stenchaetothrips biformis (Bagnall, 1913)	A	phyto-phagous	Asia-Tropical	1913, GB	CZ, GB, IT, NL, PL, RO	J100	Growing tips of seedling rice, *Oryza sativa* (larva, adult); secondary hosts: maize, *Zea mays*, wild sugarcane, *Saccharum spontaneum*, wild grasses (*Agropyron*- wheatgrass, *Festuca*-fescues, *Pennisetta*)	Bagnall (1913), Kucharczyk and Zawirska (2001), Vierbergen (2004)
Stenchaetothrips spinalis Reyes, 1994	A	phyto-phagous	Asia-Temperate	1999, FR	FR	I2	Bambusoideae	Streito and Martinez (2005)
Thrips australis (Bagnall, 1915)	A	phyto-phagous	Australasia	1930, CY	CY, ES, ES-CAN, FR, GR, IT, IT-SIC, PT, PT-AZO, PT-MAD	I2, F6	*Eucalyptus, Melaleuca*	Priesner (1964a), Priesner (1964b), Zur-Strassen (1973b), Zur-Strassen and Borges (2005)
Thrips palmi Karny, 1925	A	phyto-phagous	Asia-Tropical	1995, PT	CZ, NO, PT	I, J	Quarantine pest, polyphagous but a threat to glasshouse ornamental and vegetable crops in Europe	Anonymous (2004), Cannon et al. (2007)
Thrips simplex Morrison, 1930	A	phyto-phagous	Africa	1946, FR	AT, BG, CH, CZ, DE, ES, ES-CAN, FR, GB, HU, IL, IT, NO, NL, PT, PT-AZO, RO, SE, SI, UA	I2, J100	*Gladiolus*, polyphagous in greenhouses	Aitkenhead (1951), Bournier (1954), Zur-Strassen and Borges (2005), Milevoj et al. (2008)

Table 13.1.2. List and main characteristics of some Thysanoptera species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 03/02/2010

Family Species	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aeolothripidae						
Aeolothrips fasciatus (L., 1758)	predator/ phytophagous	Europe	PT- AZO	E, I	Both a pollen feeder and a predator of onion thrips; *Taraxacum officinale*, *Trifolium repens*, *Epilobium angustifolium*, Grasses	Zur-Strassen and Borges (2005)
Rhipidothrips gratiosus Uzel, 1895	phytophagous	Europe	GB	I,J	Grasses, wild oats	Mound et al. (1976)
Phlaeothripidae						
Apterygothrips pinicolus Pelikan & Schliephake, 1994	phytophagous	Europe	DE, CZ	G3	*Pinus*	Pelikán and Schliephake (1994)
Hoplandrothrips consobrinus (Knechtel, 1951)	mycophagous	Europe	ES- CAN, PT- AZO	U	Dead wood or leaf-litter	Zur-Strassen and Borges (2005)
Hoplothrips ulmi (F., 1781)	mycophagous	Europe	PT- AZO	G	Dead wood of broadleaved trees, feeding on fungi (possibly *Peniophora*)	Zur-Strassen and Borges (2005)
Liothrips vaneeckei Priesner, 1920	phytophagous	Europe	GB	J100	Lilly bulbs	Bagnall (1933), Mound et al. (1976)
Thripidae						
Aptinothrips rufus Haliday, 1836	phytophagous	Europe	PT- AZO	I	Grasses, cereals	Zur-Strassen and Borges (2005)
Chirothrips manicatus Haliday, 1836	phytophagous	Europe	PT- AZO	I	*Alopecurus pratensis*, *Lilium*, clover, peach, pear, apple, grasses, wheat	Zur-Strassen and Borges (2005)
Euphysothrips minozzii Bagnall, 1926	mycophagous	Europe	AT	U	Fungi infecting weeds	Zur-Strassen (2003)
Limothrips cerealium Haliday, 1836	phytophagous	Europe	PT- AZO	E, I, J	Poaceae	Zur-Strassen and Borges (2005)
Odontothrips meliloti Priesner, 1951	phytophagous	Europe	GB	G3, G4	*Melilotus*	Pitkin (1972), Mound et al. (1976)
Thrips tabaci Lindeman, 1889	phytophagous	Europe	GB	I1, I2, FA, E2, E5	Polyphagous (weeds, flowers, trees and crops)	Bagnall (1923)

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Psocids (Psocoptera) Chapter 13.2

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Abstract

Among the 231 species of Psocoptera present in Europe, 49 (21.2%) are considered to be of alien origin. They include 29 exotic introduced species and 20 cryptogenic species. Most of the exotic species originated from tropical and subtropical areas, essentially from Africa. Many of them are food pests, moving along with stored products. Thirty-nine of these species occur in buildings in Europe.

Keywords

Psocoptera, psocids, domestic, stored products, alien, Europe

13.2.1 Introduction

Psocoptera (commonly called psocids) are one of the smaller orders of paraneopteran insects. Many species are arboreal, but a few are more usually found on low vegetation or in litter. All feed on microflora and organic debris. Some are found in nests of birds and mammals, within aggregations of other insects or associated with human habitations. The head of these usually soft bodied pterygote insects (with a body length of 0.67 mm to 8 mm) is globulous with an usually prominent clypeus and projecting eyes, long and filiform antennae and biting mouthparts, the laciniae being characteristic for the order. Adults have usually four wings with simple venation. However, many species are brachypterous, micropterous or apterous (Lienhard 1998, Lienhard and Smithers 2002, Mockford 1993, New 2005).

13.2.2 Taxonomy of Psocoptera species alien *to* Europe

According to Lienhard (1998) (Lienhard 1998) a total of 231 species in 25 families of psocopterans are present in Europe. Forty-nine of these are not native, 29 as aliens to Europe and 20 as cryptogenic, globally accounting for 21,2% of the total psocopteran fauna in Europe (Figure 13.2.1). They are included in 12 families: Lepidopsocidae (5), Trogiidae (4), Psoquillidae (3) and Psyllipsocidae (5) belonging to the suborder Trogiomorpha; Liposcelididae (14) and Pachytroctidae (2) belonging to the suborder Troctomorpha; and Caeciliusidae (1), Ectopsocidae (10), Elipsocidae (1), Lachesillidae (2), Peripsocidae (1) and Psocidae (1) belonging to the suborder Psocomorpha. Details for each family are as follows.

Lepidopsocidae: Adult wings of lepidopsocids, which belong to the family group Atropetae, are generally pointed apically when fully developed. Body and forewings are generally covered with scales, but occasionally with dense setae Mockford 1993. The five species found in Europe are all alien.

Trogiidae: Species in this family, which belongs to the family group Atropetae, are apterous, micropterous or brachelytropterous. Body and forewings lack scales and dense setae. Four of the 19 species found in Europe are cryptogenic (21%). These four species are brachelytropterous, presenting short, leathery winglets similar to short elytra. Their habitats are associated with humans, e.g. within buildings and glasshouses (Lienhard 1998, Mockford 1993).

Psoquillidae: Body and forewings of species in this family, which also belongs to the family group Atropetae, do not bear scales. The three species currently found in Europe are not believed to be native, two of them being with certainty of alien origin and the third cryptogenic. All occur within buildings in Europe.

Psyllipsocidae: This family belongs to the family group Psocatropetae. The five species found in Europe (100%) are either alien (Baz 1990) or cryptogenic species (Baz 1988). All are usually found in buildings and glasshouses in Europe.

Liposcelididae: These psocids belong to the family group Nanopsocetae. They are characterised by a flattened body and antennae with secondary annulations on their flagellum. Fourteen species out of the 39 (36%) found in Europe are either aliens (Broadhead 1950) or cryptogenic species (Broadhead 1954b). They include exclusively apterous species, all of which being occur in buildings.

Pachytroctidae: The body shape of the species of this family, which belongs to the family group Nanopsocetae, is not flattened dorsoventrally and the basal flagellar segments are not secondarily annulated (New 2005). Only three species live in Europe, and two of them are not natives (67%).

Caeciliusidae: This family belongs to the family group Caeciliusetae and to the superfamily Caecilioidea. The species are characterised by the presence of at least one, or more commonly two or three, ventral abdominal vesicles (Mockford 1993). The family was once named Caeciliidae, but the latter name was changed because of homonymy with a family of amphibians (Lienhard 1998). Only one species out of the 15 (7%) found in Europe is cryptogenic. *Lacroixiella martini*, is only known by the two syntypes collected by Lacroix in 1918 in a french military hospital (Lacroix 1919).

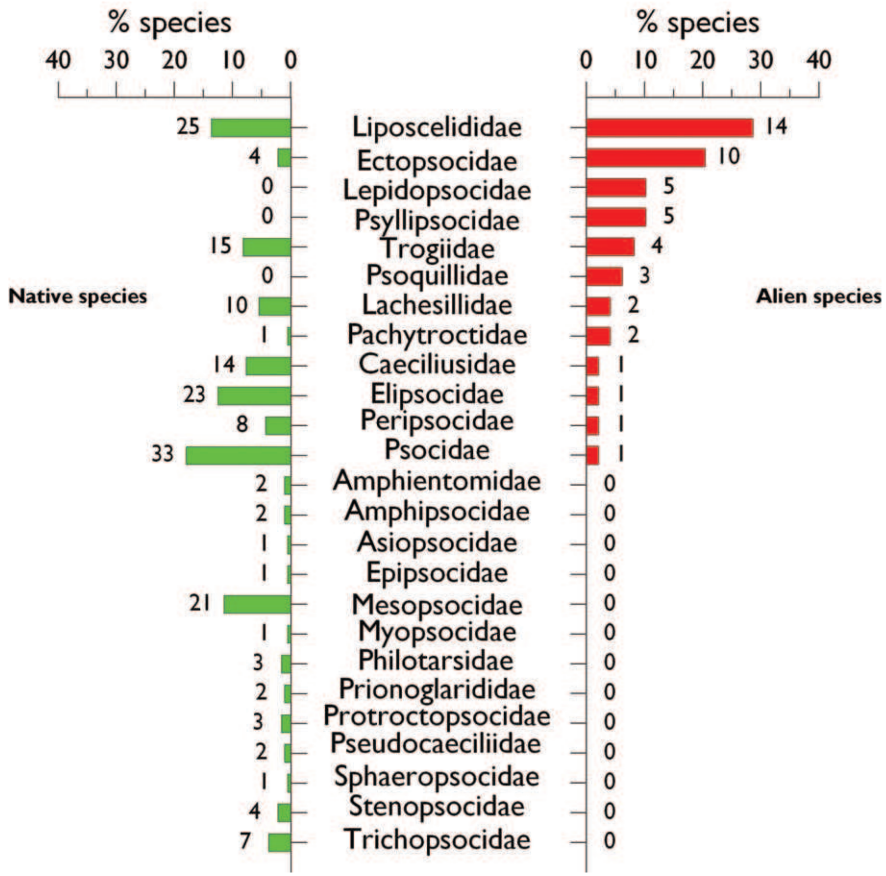

Figure 13.2.1. Taxonomic overview of the Psocoptera species alien *to* Europe compared to the native fauna. Species alien to Europe include cryptogenic species. Families are listed in a decreasing order based on the number of alien species. The number over each bar indicates the number of species observed per family.

Lachesillidae: These psocids belong to the family groupe Homilopsocidea. The species have an *areola postica** in their forewings characterized by a very sparse and short ciliation on its veins and margin. The *lacinial** tip of the Lachesillidae is slender and *bicuspid* *(Lienhard 1998, Mockford 1993). Two species out of the 12 found in Europe are aliens (17%).

Ectopsocidae: Members of this family, which belongs to the family group Homilopsocidea, are characterised by the absence of an areola postica in their wings such as in the family Peripsocidae. Ten out of the 14 species found in Europe (71%) are either alien (Broadhead 1950) or cryptogenic species (Baz 1988). Six of these species are found occurring within buildings, either regularly (Baz 1990) or sometimes (Baz 1990), compared to only one of the 4 native species.

Peripsocidae: Species of this family, which also belongs to the family group Homilopsocidea, are also characterised by their absence of an areola postica in their wings. *Peripsocus bivari* is the only alien among nine species found in Europe (11%).

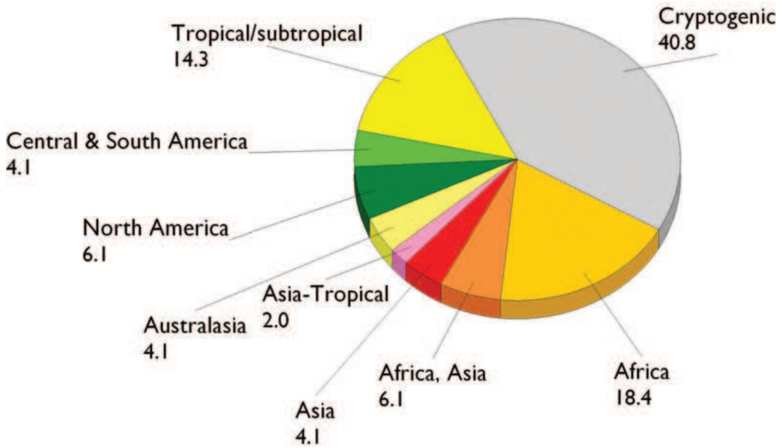

Figure 13.2.2. Geographic origin of the Psocoptera species alien *to* Europe. Numbers indicate the relative proportion of alien species originating from a given region.

Elipsocidae: Veins and wing margins of species in this family, which also belongs to the family group Homilopsocidea, bear setae but the hindwing marginal setae are limited to the radial fork (New 2005). *Propsocus pulchripennis*, occurring out-of-doors in France, Great Britain and Madeira, is the only alien among 24 species found in Europe (4%). The native range of this widespread species is the coastal regions of subtropical countries (Lienhard 1998, Lienhard and Smithers 2002).

Psocidae: This family belongs to the family group Psocetae. Its members are easily recognised by their wing venation, where the areola postica is fused to the M-vein. The Psocidae fauna of Europe includes 34 species but *Trichadenotecnum innuptum* is the only alien among them (3%).

13.2.3 Temporal trends of introduction in Europe of alien psocids

The cryptogenic species *Trogium pulsatorium* was already known as *Termes pulsatorium* in the 10th edition of Systema Naturae by Linnaeus in 1758 (Linnaeus 1958). From 1850 to 1874, three other cryptogenic species and the alien *Psoquilla marginepunctata* were recorded from Europe. One alien and one cryptogenic species followed in 1899. In the 20th century, seven species on our list were recorded for the first time in Europe from 1900 to 1924, 18 from 1925 to 1949, seven from 1950 to 1974 and finally ten from 1975 to 1999. In the 21st century, no new alien has arrived in Europe to date.

13.2.4 Biogeographic patterns of the Psocoptera species alien *to* Europe

The distribution status is only known for 29 species out of 49, 40.8% being thus considered as cryptogenic. Figure 13.2.2 details the probable regions of origin. Most

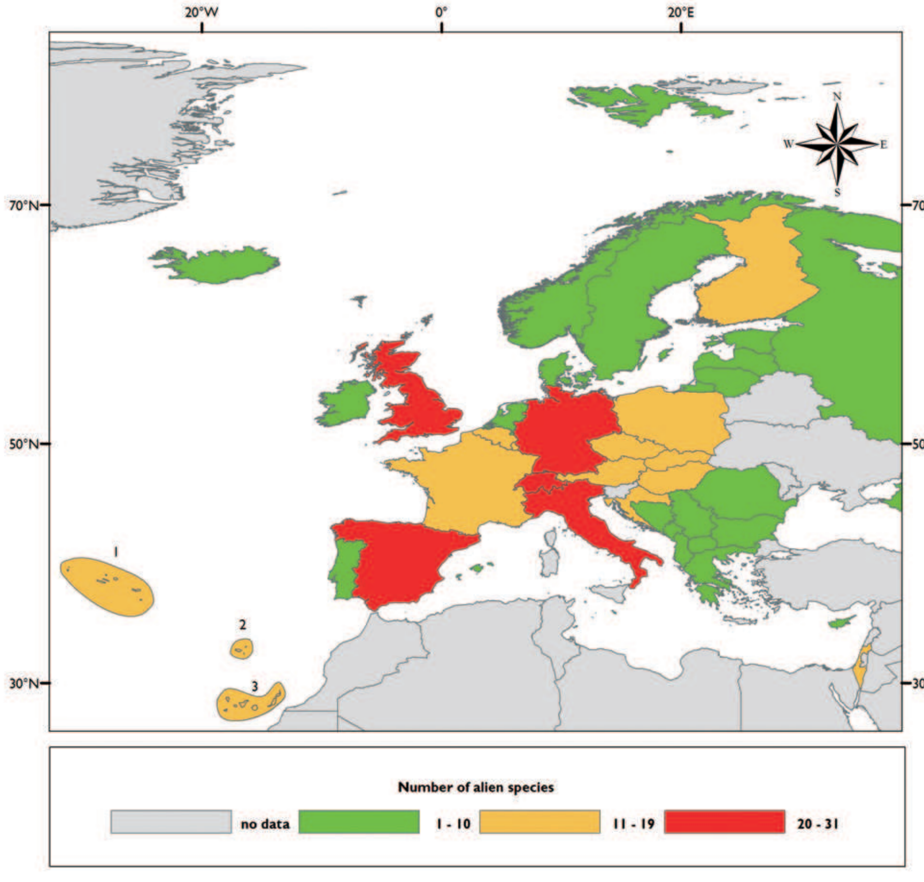

Figure 13.2.3. Colonization of continental European countries and main European islands by the Psocoptera species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

species appear to originate from Africa (9 species, 18.4 %), far beyond the other continents but for seven species (14.3%) we only know that they arrived from tropical and subtropical regions. Central and Western Europe appear to be more colonized by alien psocids (Figure 13.2.3).

13.2.5 Pathways of introduction in Europe of alien psocids, invaded habitats and known impacts

The main pathway of introduction is trade. *Lachesilla pacifica* is probably dispersed by wind. Most aliens and cryptogenic species are found in warehouses in stored products. Many of them are food pests. Forty species (88.9 %) are associated with buildings in Europe.

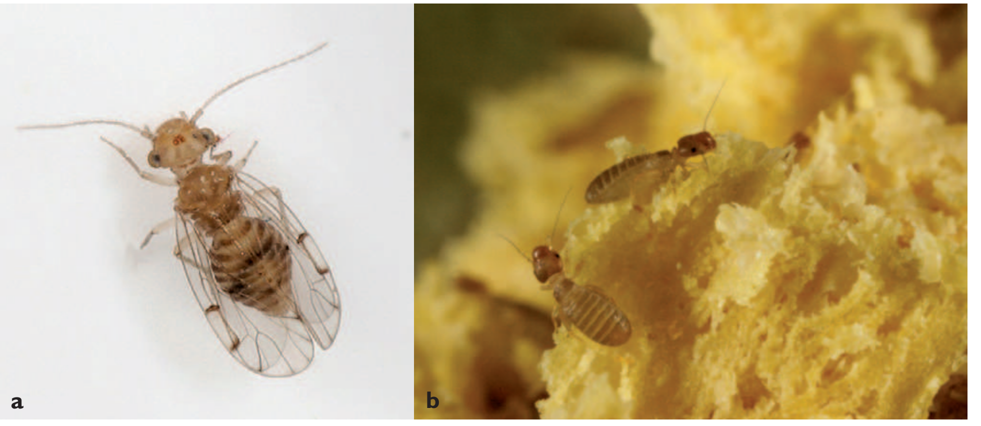

Figure 13.2.4. Alien psocids**. a** *Ectopsocus briggsi* McLachlan, 1899 (Credit: Tom Murray 2008) **b** *Liposcelis bostrychophila* Badonnel, 1931 (Credit: Joyce Gross 2006).

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References

Badonnel A (1943) *Psocoptères. Faune de France 42.* Paris: Lechevallier et fils. 164 pp.

Baz A (1988) Psocopteros de Azores: nuevas citas, descripciones y sinonimias; *Boletim da Sociedade Portuguesa de Entomologia* 93: 1–15.

Baz A (1990) *Nanopsocus oceanicus* Pearman, 1928, nueva especie para la fauna de Europa (Psocoptera, Pachytroctidae). *Nouvelle Revue d'Entomologie* 7: 251–254.

Bigot L (1982) Structure et dynamique des populations frondicoles d'insectes Coléoptères et Psocoptères dans la Forêt de la Sainte-Baume. *Bulletin du Muséum d'Histoire naturelle, Marseille* 42: 7–18.

Broadhead E (1947) New species of *Liposcelis* Motschulsky (Corrodentia, Liposcelidae) in England .*Transactions of the Royal Entomological Society of London* 98: 41–58.

Broadhead E (1950) A revision of the genus *Liposcelis* Motschulsky with notes on the position of this genus in the order Corrodentia and on the variability of ten *Liposcelis* species. *Transactions of the Royal Entomological Society of London* 98: 41–58.

Broadhead E (1954a) a A new parthenogenetic psocid from stored products, with observations on parthenogenesis in other psocids. *Entomologist's Monthly Magazine* 90: 10–16.

Broadhead E (1954b) The infestation of warehouses and ships' holds by psocids in Britain. *Entomologist's Monthly Magazine* 90: 103–105.

Broadhead E (1955) Two new psocid species from stored products in Britain. *Proceedings of the Royal Entomological Society of London (B)* 24(1/2): 7–12.

Danks L (1955) Psocoptera of the Batumi and Sochi Botanic Gardens. *Entomologicheskoe Obozrenie* 34: 180–184.

Eichler W (1938) *Thylacopsis madagascariensis*, *Brachymyrmex heeri* und *Ptilodactyla luteipes* in einem Dahlemer Gewächshaus (Studien zur deutschen Gewächshausfauna II). *Zoologischer Anzeiger* 122: 330–333.

Enderlein G (1905) Morphologie, Systematik und Biologie der Atropiden und Troctiden, sowie Zusammenstellung aller bisher bekannten recenten und fossilen formen. *Results of the Swedish Zoological Expedition to Egypt and the White Nile, 1901* 18, 1–58.

Enderlein G (1906) Zehn neue aussereuropäische Copeognathen. *Stettiner Entomologische Zeitung* 67: 306–316.

Günther KK (1974) *Staubläuse, Psocoptera. Die Tierwelt Deutschlands 61*. Jena: G. Fischer. 314 pp.

Hagen H (1865) Synopsis of the Psocina without ocelli. *Entomologists' Monthly Magazine* 2: 121–124.

Harrison JWH (1916) A November week at Grange-over-sands V Psocoptera collected by Richard S Bagnall, FLS. *Lancashire Naturalist* 9: 197–109.

Heyden CHG von (1850) Zwei neue deutsche Neuropteren-Gattungen. *Stettiner Entomologische Zeitung* 11: 83–85.

Heymons R (1909) Ein neuer *Troctes* als Schädling in Buchweizengrütze (Corrod). *Deutsche Entomologische Zeitschrift* 1909: 452–455.

Jentsch S (1939) Beiträge zur Kenntnis der Überordnung Psocoidea 8 Die Gattung *Ectopsocus* (Psocoptera). *Zoologische Jahrbücher (Abteilung Sytematik)* 73: 111–128.

Lacroix J (1919) Description d'un Psocide nouveau de France. *Bulletin de la Société entomologique de France* 1919: 80–81.

Lienhard C (1977) Die Psocopteren des schweizerischen Nationalparks und seiner Umgebung (Insecta: Psocoptera). *Ergebnisse der wissenschaftlichen Untersuchungen im Schweizerischen Nationalpark* 14: 417–551.

Lienhard C (1985) Sur quelques espèces intéressantes de Psocoptères du Bassin Lémanique et du Valais. Bulletin Romand d'Entomologie 3: 73–79.

Lienhard C, (1986) Beitrag zur Kenntnis der Psocopteren-Fauna Ungarns (Insecta). *Annales Historico-naturales Musei nationalis Hungarici* 78: 73–78.

Lienhard C (1994) Staubläuse (Psocoptera) – ungebetene Gäste in Haus und Vorrat. *Mitteilungen der Entomologischen Gesellschaft Basel, Neue Folge* 44: 122–160.

Lienhard C (1996) Psocoptères nouveaux ou peu connus de quelques îles atlantiques (Canaries, Madère, Açores, Ascension) et de l'Afrique du Nord (Insecta: Psocoptera). *Boletim do Museu Municipal do Funchal (Historia Natural)* 48: 87–151.

Lienhard C (1998) *Psocoptères euro-méditerranéens Faune de France 83*. Paris : Fédération Française des Sociétés de Sciences Naturelles. 517 pp.

Lienhard C, Schneider, N (1993) *Dorypteryx longipennis* Smithers, un psoque domicole nouveau pour l'Europe (Psocoptera: Psyllipsocidae). *Bulletin et Annales de la Société Royale Belge d'Entomologie* 129: 129–137.

Lienhard C, Smithers CN (2002) *Psocoptera (Insecta): World Catalogue and Bibliography. Instrumenta Biodiversitatis 5*. Genève: Muséum d'Histoire Naturelle. 745 pp.

Lienhard C (2002–2009). Additions and Corrections to Lienhard & Smithers, 2002 Psocoptera (Insecta) : World Catalogue and bibliography. *Psocid News* 4 (2002), 6 (2004), 7 (2005), 8 (2006), 9 (2007), 10 (2008) and 11 (2009). http://www.psocodea.org/psocid_news.

Linnaeus C von (1758) *Systema Naturae per Regna tria Naturae, secundem Classes, Ordines, Genera, Species, cum Characteribus, Differentis, Synonymis, Locis. Tom.1, Editio decima, reformata*. Holmiae: Laurentii Salvii. 824 pp.

McLachlan R (1899) *Ectopsocus briggsi*, a new genus and species of Psocidae found in England. *Entomologists' Monthly Magazine* 35: 277–278.

Mockford E L (1993) *North American Psocoptera (Insecta). Flora and Fauna Handbook 10*. Gainesville, Florida: Sandhill Crane Press. 455 pp.

Motschulsky V von (1852) Etudes entomologiques. (Psocids: Excursions entomologiques de *1852*, jusqu'au 1 Juillet). *Helsingfors*: 19–20.

New TR (2005) *Psocids, Psocoptera (Booklice and barklice). Handbooks for the Identification of British Insects Vol 1, Part 7*. London: Royal Entomological Society. 146 pp.

Pearman JV (1925) Additions to the British psocid fauna. *Entomologist's Monthly Magazine* 61: 124–129.

Pearman JV (1929) New species of Psocoptera from warehouses. *Entomologist's Monthly Magazine* 65: 104–109.

Pearman JV (1931a) A new species of *Lepinotus* (Psocoptera). *Entomologist's Monthly Magazine* 67: 47–50.

Pearman JV (1931b) More Psocoptera from warehouses. *Entomologist's Monthly Magazine* 67: 95–98.

Pearman JV (1932) A new species of *Tapinella* (Psocoptera). *Stylops* 1: 240–242.

Pearman JV (1942) Third note on Psocoptera from warehouses. *Entomologist's Monthly Magazine* 78: 289–292.

Pearman JV (1946) A specific characterization of *Liposcelis divinatorius* (Müller) and *mendax* sp n (Psocoptera). *Entomologist* 79: 235–244.

Ribaga C (1899) Descrizione di nuovo genere e di nuova specie di Psocidi trovato in Italia. *Rivista di Patologia Vegetale* 8: 156–159.

Ribaga C (1904) Sul genere *Ectopsocus* MacLachl e descrizione di una nuova varietà dell' *Ectopsocus briggsi* MacLachl. *Redia* 1: 294–298.

Ribaga C (1907) Copeognati nuovi. *Redia* 4: 181–189.

Selys-Longchamps E de (1872) Notes on two new genera of Psocidae. *Entomologist's Monthly Magazine* 9: 145–146.

Titschack E (1930) Die Copeognatha, Megaloptera, Neuroptera und Mecoptera der näheren und weiteren Umgebung Hamburgs. *Verhandlungen des Vereins für Naturwissenschaftliche Heimatforschung* 21: 104–127.

Table 13.2.1. List and main characteristics of the Psocoptera species alien *to* Europe. Status: A: Alien *to* Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Last update 31/ 12/ 2009

Family *Species*	**Status**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**References**
Caeciliusidae						
Lacroixiella martini (Lacroix, 1919)	C	Unknown	1918, FR	FR	U	Lacroix (1919), Lienhard (1998), Lienhard and Smithers (2002)
Ectopsocidae						
Ectopsocopsis cryptomeriae (Enderlein, 1907)	A	Asia	1955, RU	AT, CH, DE, HR, HU, IL, IT, RU, YU	G, I, J, X	Danks (1955), Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009)
Ectopsocus axillaris (Smithers, 1969)	A	?Australia	1991, IE	GB, IE	G	Lienhard (1998), Lienhard and Smithers (2002)
Ectopsocus briggsi McLachlan, 1899	C	Unknown	1899. GB	AT, BE, CH, CY, CZ, DE, EE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IE, IL, IT, LU, ME, MK, NL, NO, PT, PT-AZO, PT-MAD, PL, RS, RU, SE, YU	G, I, X	Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), McLachlan (1899)
Ectopsocus maindroni Badonnel, 1935	A	Tropical, subtropical	1954, GB	GB, IT	J	Broadhead (1954b), Lienhard (1998), Lienhard and Smithers (2002)
Ectopsocus meridionalis Ribaga, 1904	C	Unknown	1904, IT	AT, CH, CY, CZ, DE, ES, ES-CAN, FR, GR, HR, HU, IE, IL, IT, LU, ME, MK, MT, RO, RS, YU	J, X	Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), Ribaga (1904)
Ectopsocus pumilis (Banks, 1920)	A	Africa, Asia	1984, PT-AZO	CH, PT-AZO	J	Lienhard (1994), Lienhard (1998), Lienhard and Smithers (2002), Mockford (1993)
Ectopsocus richardsi (Pearman, 1929)	A	Africa, Asia	1929, GB	CH, GB, PT-AZO	J	Lienhard and Smithers (2002), Pearman (1929)
Ectopsocus rileyae Schmidt & Thornton, 1993	A	Australia	1992, PT-MAD	PT-MAD	G	Lienhard (1996, 1998), Lienhard and Smithers (2002)
Ectopsocus strauchi Enderlein, 1906	A	?Africa	1906, ES-CAN	ES, ES-CAN, IT, PT-AZO, PT-MAD	J	Enderlein (1906), Lienhard (1998), Lienhard and Smithers (2002)
Ectopsocus titschacki Jentsch, 1939	A	C. & S. America	1928, DE	DE, ES	G, J	Jentsch (1939), Lienhard (1998), Lienhard and Smithers (2002)
Elipsocidae						
Propsocus pulchripennis (Perkins, 1899)	A	Tropical, subtropical	1981, PT-MAD	FR, GB, PT-MAD	X	Baz (1990), Bigot (1982), Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009)
Lachesillidae						
Lachesilla pacifica Chapman, 1930	A	North America	1986, CH	CH, FR	G	Lienhard (1998), Lienhard and Smithers (2002)

Family *Species*	**Status**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**References**
Lachesilla tectorum Badonnel, 1931	A	Tropical, subtropical	1992, PT-MAD	ES-CAN, PT-MAD	G, I, X	Lienhard (1998), Lienhard and Smithers (2002)
Lepidopsocidae						
Echmepteryx madagascariensis (Kolbe, 1885)	A	Tropical, subtropical	1938, DE	DE	J	Eichler (1938), Lienhard (1998), Lienhard and Smithers (2002)
Lepolepis bicolor Broadhead, 1955	A	Africa, Asia	1945, GB	GB	J	Broadhead (1955), Lienhard (1998), Lienhard and Smithers (2002)
Nepticulomima sakuntala Enderlein, 1906	A	Asia, tropical	1954, GB	GB	J	Broadhead (1954b), Lienhard (1998), Lienhard and Smithers (2002)
Pteroxanium kelloggi (Ribaga, 1905)	A	North America	1916, GB	FR, GB, IE, PT-MAD	J, X	Harrison (1916), Lienhard (1998), Mockford (1993)
Soa flaviterminata Enderlein, 1906	A	Tropical, subtropical	1930, DE	DE, GB	J	Lienhard (1998), Lienhard and Smithers (2002), Selys-Longchamps (1872)
Liposcelididae						
Belaphotroctes ghesquierei Badonnel, 1949	A	?Africa	1993, ES-CAN	ES-CAN	J	Lienhard (1996)
Embidopsocus minor (Pearman, 1931)	A	Africa	1931, GB	GB	J	Lienhard (1998), Lienhard and Smithers (2002), Pearman (1931b)
Liposcelis albothoracica Broadhead, 1955	A	Africa	1955, GB	GB	J	Broadhead (1955), Lienhard (1998), Lienhard and Smithers (2002)
Liposcelis bostrychophila Badonnel, 1931	C	Unknown	1943, FR	AT, BE, CH, CY, CZ, DE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IE, IL, IT, LU, MK, MT, NL, NO, PT, PT-AZO, PT-MAD, PL, RO, RS, SE, YU	J	Badonnel (1943), Lienhard (1998), Lienhard and Smithers (2002)
Liposcelis brunnea Motschulsky, 1852	C	Unknown	1852, RU	AT, BE, CH, CY, CZ, DE, ES, ES-CAN, FI, FR, GB, GR, HR, IT, LU, MK, NO, PL, PT, RO, RS, SE, RU, YU	J	Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), Motschulsky (1852)
Liposcelis corrodens (Heymons, 1909)	C	Unknown	1909, DE	AT, BE, CH, CY, CZ, DE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LU, MK, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, SE, YU	G, J	Heymons (1909), Lienhard (1998), Lienhard and Smithers (2002)

Family *Species*	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Liposcelis decolor (Pearman, 1925)	C	Unknown	1925, GB	AT, BE, CH, CY, CZ, DE, EE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IL, IT, LU, LV, MK, MT, NL, NO, PL, PT, PT-MAD, RO, SE, YU	J	Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002), Pearman (1925)
Liposcelis entomophila (Enderlein, 1907)	C	Unknown	1929, GB	CH, CY, CZ, DE, ES, FI, GB, HR, IL, IT, PT, PT-AZO, YU	J	Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), Pearman (1929)
Liposcelis mendax Pearman, 1946	A	Africa	1946, FR, GB	CH, ES, ES-CAN, FR, GB, HR, IT, YU	J	Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), Pearman (1946)
Liposcelis obscura Broadhead, 1954	A	?Africa	1954, GB	GB	J	Broadhead (1954a), Lienhard (1998), Lienhard and Smithers (2002)
Liposcelis paeta Pearman, 1942	C	Unknown	1940, GB	BE, CZ, ES, GB, HR, IT, YU	J	Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), Pearman (1942)
Liposcelis paetula Broadhead, 1950	C	Unknown	1945, GB	ES-CAN, GB, IT, PT-MAD	G, J	Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002)
Liposcelis pearmani Lienhard, 1990	A	?Asia	1945, GB	AT, CH, CZ, DE, ES, FI, FR, GB, HR, HU, IL, IT, LU, NL, YU	J	Broadhead (1950), Lienhard (1998), Lienhard (2002–2010), Lienhard and Smithers (2002)
Liposcelis pubescens Broadhead, 1947	C	Unknown	1943, GB	BE, CH, CZ, DE, GB, IT, LU, PT-AZO, YU	J	Broadhead (1947), Broadhead (1950), Lienhard (1998), Lienhard and Smithers (2002)
Pachytroctidae						
Nanopsocus oceanicus Pearman, 1928	A	Tropical, subtropical	1988, ES	CY, ES, ES-CAN	J	Baz (1990), Lienhard (1998), Lienhard and Smithers (2002)
Tapinella castanea Pearman, 1932	C	Unknown	1932, GB	ES-CAN, GB	J	Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009), Pearman (1932)
Peripsocidae						
Peripsocus bivari Baz 1988	A	?Africa	1979, PT-AZO	ES-CAN, FR, PT-AZO,PT-MAD	G, X	Baz (1988), Lienhard (1996, 1998), Lienhard and Smithers (2002)
Psocidae						
Trichadenotecnum innuptum Betz, 1983	A	North America	1965, HU	CH, HU, IT	G, X	Lienhard (1986, 1998), Lienhard and Smithers (2002)
Psoquillidae						
Psoquilla marginepunctata Hagen, 1865	A	C. & S. America	1865, ?DE	BE, CZ, ?DE, GB, IT, PT-AZO	G, J	Günther (1974), Hagen (1865), Lienhard and Smithers (2002)

Family *Species*	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Rhyopsocus disparilis (Pearman, 1931)	A	Africa	1931, GB	GB	J	Lienhard (1998), Lienhard and Smithers (2002), 38
Rhyopsocus peregrinus (Pearman, 1929)	C	Unknown	1929, GB	GB	J	Lienhard (1998), Lienhard and Smithers (2002), Peramn (1929)
Psyllipsocidae						
Dorypteryx domestica (Smithers, 1958)	A	Africa	1973, CH	AT, BA, BE, CH, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, HR, HU, IE, IL, IT, LU, NO, PL, SE, SK, YU	J	Lienhard (1977, 1998, 2002- 2010), Lienhard and Smithers (2002)
Dorypteryx longipennis Smithers, 1991	C	Unknown	1988, LU	BE, CH, ES, IE, IT, LU, NL	J	Lienhard (2002- 2010), Lienhard and Schneider (1993), Lienhard and Smithers (2002)
Dorypteryx pallida Aaron,1883	C	Unknown	1907, IT	AT, BE, CH, CZ, DE, ES, FR, IT	J	Lienhard (1998), Lienhard and Smithers (2002), Mockford (1993), Titschak (1930)
Psocathropos lachlani Ribaga, 1899	A	Tropical, subtropical	1899, IT	ES-CAN, IL, IT, PT-MAD	H, J	Lienhard (1998), Lienhard and Smithers (2002), Ribaga (1904)
Psyllipsocus ramburii Sélys-Longchamps, 1872	C	Unknown	1872, FR	AT, BE, CH, CZ, DE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IE, IL, IT, LU, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, YU	H, J	Lienhard (1998, 2002- 2010), Lienhard and Smithers (2002), Sélys- Longchamps (1872)
Trogiidae						
Lepinotus inquilinus von Heyden, 1850	C	Unknown	1850, DE	AT, BE, CH, CZ, DE, DK, ES, ES-BAL, ES-CAN, FI, FR, GB, GR, HR, HU, IS, IT, LU, NL, NO, PL, PT-AZO, PT-MAD, RO, RU, SE, YU	J	Heyden (1850), Lienhard (1998), Lienhard and Smithers (2002)
Lepinotus patruelis Pearman, 1931	C	Unknown	1930, GB	AT, BE, CH, CZ, DE, FI, FR, GB, IE, IT,LU, NO, PL, PT-AZO, SE	J	Lienhard (1998), Lienhard and Smithers (2002), Pearman (1931a)
Lepinotus reticulatus Enderlein, 1905	C	Unknown	1905, DE	AT, BE, CH, CY, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IL, IS, IT, LU, MK, NL, PT, PT-AZO, PL, RO, RU, SE, YU	J	Enderlein (1905), Lienhard (1998), Lienhard and Smithers (2002)
Trogium pulsatorium (Linnaeus, 1758)	C	Unknown	1758, Europe	AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IE, IL, IS, IT, LT, LU, NL, NO, PL, PT-AZO, PT-MAD, RO, RU, SE, YU	J	Lienhard (1998), Lienhard and Smithers (2002)

Table 13.2.2. List and characteristics of the Psocoptera species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 31/ 12/ 200

Family *Species*	**Native range**	**Invaded countries in Europe**	**Habitat**	**References**
Caeciliusidae				
Enderleinella obsoleta (Stephens, 1836)	Central Europe	BE, BG, DK, FI, FR, GB, IE, IT, LU, ME, MK, NL, NO, RO, RU, SE	G	Lienhard (1998), Lienhard and Smithers (2002)
Ectopsocidae				
Ectopsocus vachoni Badonnel, 1945	Mediterranean region	CH, GB	G, J	Lienhard (1998), Lienhard and Smithers (2002)
Lachesillidae				
Lachesilla greeni (Pearman, 1933)	Central Europe	BE, ES, FR, GB, IT, PT, PT-AZO, PT-MAD, RO	G, H, J	Lienhard (1998), Lienhard and Smithers (2002), Lienhard (2002)–(2009)
Liposcelididae				
Liposcelis rufa Broadhead, 1950	Mediterranean region	CH, GB, PL	G, J	Lienhard (1998), Lienhard and Smithers (2002)
Peripsocidae				
Peripsocus milleri (Tillyard, 1923)	Atlantic coast of Europe	IT, YU	G, J	Lienhard (1998), Lienhard and Smithers (2002)
Peripsocus parvulus Kolbe, 1880	Central Europe	BE, ES, FI, FR, GB, GR, HR, IL, LU, NL, RO, RU, SE, YU	G	Lienhard (1998), Lienhard and Smithers (2002)
Trichopsocidae				
Trichopsocus clarus (Banks, 1908)	Mediterranean region	CH, CZ, DE, FI, GB, HU, IE, LT, NL, PL, RU, SE	J, X	Lienhard (1998), Lienhard and Smithers (2002)
*Trichopsocus dali*i (McLachlan, 1867)	Mediterranean region	AT, BE, CH, CZ, DE, GB, HU, LU, PL, RU	G	Lienhard (1998), Lienhard and Smithers (2002)
Trogiidae				
Cerobasis annulata (Hagen, 1865)	Mediterranean region	AT, BE, CH, CZ, DE, GB, LU, NL, NO, PL, RU	G, J, X	Lienhard (1998), Lienhard and Smithers (2002)

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Dictyoptera (Blattodea, Isoptera), Orthoptera, Phasmatodea and Dermaptera Chapter 13.3

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Abstract

For convenience, we treat all "polyneopteran" orders together. Five orders of hemimetabolous "Polyneoptera" include species alien *to* Europe, namely Blattodea, Isoptera, Orthoptera, Phasmatodea and Dermaptera. A total of 37 species alien *to* Europe have been recorded. These belong to 14 different families. Most of these species show a detritivorous feeding regime (22 spp.), whereas 12 species are phytophagous and two are predators. The majority of species were first observed between 1900 and 1975. Unlike other arthropod groups, the mean number of polyneopteran species newly recorded per year showed no acceleration since 1975. The alien "Polyneoptera" mostly originated from Central/ South America and Asia (10 species each, 27.0%), followed by Africa (7, 18.9%). Germany hosts the largest number of alien Polyneoptera (15 spp.), followed by Denmark (14), Spain (11) and France (10). All but one alien species represent unintentional introductions. More than 75% of the species are associated with artificial habitats (houses, buildings and greenhouses) and cultivated areas. Blattodea and Isoptera have huge economic and/ or medical importance. The cost of treatments and sanitary measures against termites and cockroaches, in particular, is significant in Europe.

Keywords

Alien, Orthoptera, grasshoppers, Blattodea, coackroaches, Isoptera, termites, Phasmatodea, walking sticks, Dermaptera, earwigs

13.3.1 Introduction

For convenience, we group all the orders belonging to the "Polyneoptera" assemblage into the same chapter. This non-monophyletic assemblage of eleven "orthopteroid" orders includes five orders which contain species alien *to* Europe. Some of these orders are very familiar such as grasshoppers (Orthoptera), cockroaches (Blattodea), termites (Isoptera), earwigs (Dermaptera) and walking sticks (Phasmatodea). Lesser known groups include web-spinners (Embioptera), angel insects (Zoraptera) and ice-crawlers (Grylloblattodea). We describe here the characteristics of the species alien *to* Europe.

Blattodea contains over 4500 species worldwide, with about 150 species in Europe. They are among the most ancient winged insects, the earliest fossils dating back to the Carboniferous. The group is well defined by a combination of characters: eggs usually contained in oothecae (egg cases), leathery forewings, male genitalia asymmetrical and *cerci** with one or more segments. Most cockroaches are tropical and found in a wide variety of habitats such as dead or decaying leaves or trees, caves, under stones, in nests of social insects etc. Cockroaches are mostly scavengers eating organic material. Less than 1% (30 species) are associated with humans, but these species contribute to the unpopular reputation of these insects. Cockroaches exhibit diverse reproductive biology. Most species have sexual reproduction, but some populations of *Pycnoscelus surinamensis* are parthenogenetic. These hemimetabolous insects produce hardened oothecae deposited on a substrate or membraneous oothecae that are incubated in a brood sac within the female's body. Some species exhibit a high level of parental care.

Isoptera consists of over 2600 species (mostly tropical). Termites are the oldest social insect group with complex societies dating back at least to the early Cretaceous (140 Mya). Only 12 species occur in Europe. Recent studies have shown that Isoptera are basically social cockroaches forming a monophyletic clade within the Blattodea, most likely the sister group of the Cryptocercidae (woodroaches) (Inward et al. 2007). Termites are the only hemimetabolous insects that exhibit true social behavior. They build large nests housing an entire colony. These colonies contain adult reproductives (one queen and one king) plus hundreds or thousands of immatures that serve as workers and soldiers. Termites are important decomposer animals in lowland tropical ecosystems. They mostly feed on dead plant material and are able to digest cellulose with the help of symbiotic gut symbionts.

Orthoptera comprises more than 20000 species worldwide and 1044 species in Europe belonging to two suborders, Caelifera (grasshoppers) and Ensifera (ladykids). This group of median-sized insects is well characterized by (1) long hind legs modified for jumping; (2) hardened, leathery forewings (tegmina) which are spread in flight and covering membranous hindwings at rest; (3) unsegmented cerci; and (4), a pronotum usually with large descending lateral lobes. Orthopterans are common in most terrestrial habitats, but are more diverse in the tropics. They are mostly phytophagous and include some outstanding agricultural pests (locusts and certain katydids).

Phasmatodea (also known as Phasmida) comprises 3000 species worldwide with only 15 species known in Europe. Stick-insects are found in nearly all temperate and tropical ecosystems. Species are mostly nocturnal and phytophagous. Phasmatodea bears several common morphological characters that clearly define the order: an emarginated labrum, a pair of exocrine glands located inside the prothorax, and a thorax fused with the first abdominal sternum. Phasmids undergo an incomplete metamorphosis (four to eight instars), with the young nymphs resembling miniature, albeit wingless, adults.

Dermaptera comprises about 1800 species and about 80 species in Europe. These small- to median-sized insects have the head *prognathous** and are clearly characterized by two or more apomorphies: long unsegmented (not always forceps-like) cerci, and details of hindwing structure. The biology of Dermaptera is poorly known. Most species appear to be omnivorous but some are phytophagous and a few are predators. The development is hemimetabolous. Earwigs have larvae (four to five instars) that resemble the adult, except that the wings are only buds.

Several characteristics group species in these orders together. The polyneopteran group treated here comprises mostly phytophagous species (consuming fresh plants, dead wood or leaves), but some species are detrivorous. None of the species alien *to* Europe is parasitic and very few are predators. These species are rarely transported with cultivated plants, even if eggs of stick-insects are introduced with soil. Consequently, polyneopterans are rarely introduced into Europe through the plant trade. Most species are relatively large and conspicuous, the smallest insects belonging to Isoptera and Dermaptera. All of them are hemimetabolous and consequently their larvae are biologically similar to adults. The diversity of these groups in the Holarctic region is relatively limited and most species are tropical. These characteristics may partly explain the relatively low number of species in the alien fauna that has colonized Europe, compared to worldwide Polyneopteran diversity.

13.3.2. Taxonomy of alien species

A total of 37 species alien *to* Europe have been recorded. These species belong to five different orders and 14 different families (Table 13.3.1; Figure 13.3.1). Blattodea account for 18 species and is the order with by far the greatest number of aliens to Europe. Eleven species belong to Orthoptera, four to Phasmatodea, while Dermaptera and Isoptera include two alien species each. Within Orthoptera, Ensifera are well representated with seven species (63% of Orthoptera). Among these alien species, 22 are detritivorous, 12 phytophagous and two are predators, the biology of one species being unknown. This results show that within invasive Polyneoptera, a majority of species are detritivorous or phytophagous (94%). Table 13.3.2 presents some species of the same orders considered as alien in Europe (native to a European region but introduced in another through human activity).

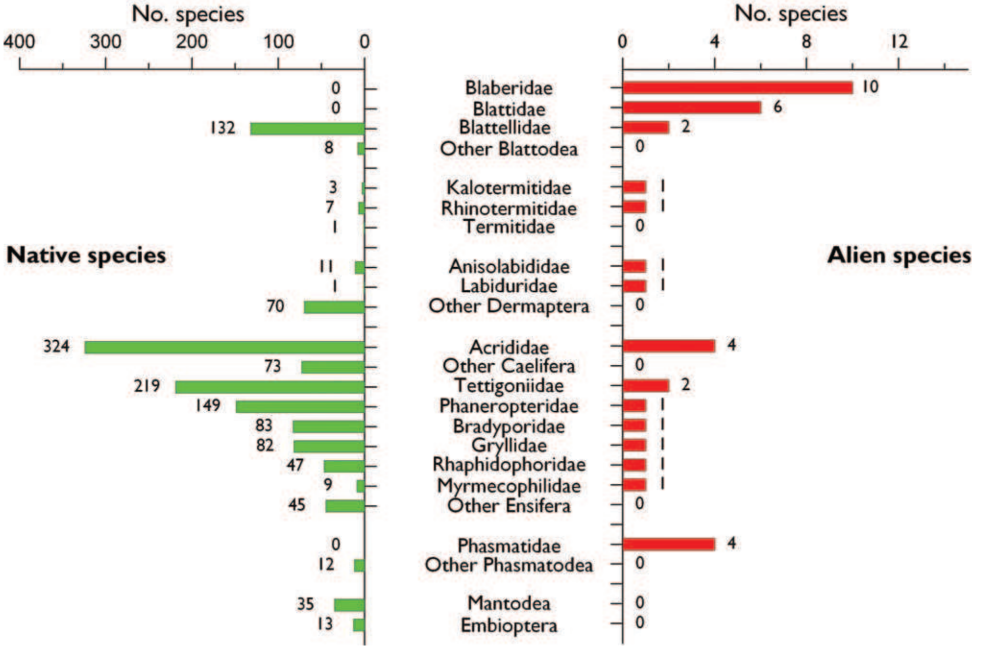

Figure 13.3.1. Relative importance of the families of Blattodea, Isoptera, Orthoptera, Phasmatodea, and Dermaptera in the alien and native entomofauna *in* Europe. Families are presented per order in a decreasing ranking based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of species observed per family.

Blattodea

Blaberidae. This small family contains ten species in Europe, all of them introduced from tropical countries. These cockroaches are ovoviviparous, some species being parthenogenetic. Several Blaberidae species have been introduced into urban areas of Europe. Among them, *Blaberus atropos* is a native to South America that exhibits a death's-head markings on the mesonotum and metanotum. *Nauphoeta cinerea* lives mostly around the outside of buildings but also occurs in houses. *Panchlora nivea* is commonly associated with bananas and palm trees. This species was introduced in Northern Europe with shipments of bananas. *Pycnoscelus surinamensis*, a Malaysian cockroach, as been introduced several times to Europe. It occurs in greenhouses and cannot live outdoors. Its European populations appear to be parthenogenetic. This trait has been wrongly identified to explain the strong invasive ability of this cockroach (Grandcolas et al. 1996). *Rhyparobia maderae*, an afrotropical cockroach, was probably transported to southern Europe with banana shipments and occurs indoors.

Blattellidae. Among the ca. 135 species of Blatellidae occurring in Europe, only two species, *Nyctibora laevigata* and *Supella longiplapa,* have an alien origin, both having been introduced from tropical regions. The last one is an afrotropical species with synanthropic habits, occurring in houses and greenhouses in Europe. These long- legged cockroaches carry the eggcase externally.

Blattidae. Only six species are known in Europe, all of them having been introduced from tropical or subtropical regions. *Blatta orientalis*, *Periplaneta* spp. and *Neostylopyga rhombifolia* are synanthropic species that have long been introduced to Europe. A more recent arrival is that of *Shelfordella lateralis,* the Turkestan cockroach, which has been discovered in 2007 in Cagliari, Sardinia. This species has previously been introduced in the 1970s in the Southern United States (California, Texas, Arizona) probably with military people coming back from the Middle East (Fois et al. 2009). These blattid species mostly develop indoors, in heated buildings but can also develop in greenhouses and in the city streets.

Isoptera

Kalotermitidae. This family comprises only four species in Europe, of which only *Cryptotermes brevis* is alien *to* Europe. This species infests dry wood and can damage woodwork, furniture and floors. *C. brevis* has been found both in Northern and Southern Europe but it has been more widely introduced to tropical countries. Recent studies showed that the early European shipment of exports from coastal Peru and Chile caused the release and initial dispersal of *C. brevis* from its natural range (Scheffrahn et al. 2009).

Rhinotermitidae. This family comprises seven species in Europe, including one alien species originating from North America, *Reticulitermes flavipes* (= *R. santonensis* (Feytaud); see Austin et al. 2005), where it is considered to be a significant pest. Subterannean termites in the genus *Reticulitermes* Holmgren (Isoptera: Rhinotermitidae) are the major termite pests infesting wooden structures in Europe and the near East.

Dermaptera

Anisolabididae. This family comprises 12 species in Europe. *Euborellia stali*, of Asian origin, preys on stem borers associated with rice entering the borer tunnel. This widespread species has recently been introduced in Italy.

Labiduridae. Only two species of Labiduridae are known from Europe, including a species originating from tropical/subtropical regions, *Nala lividipes.* This species is considered as a pest with local economic importance, but it is rare in Europe.

Orthoptera

Acrididae (Caelifera). This diverse family (about 350 species in Europe) only contains four species alien to Europe. Furthermore, the status of two of them, *Notaustorus albicornis* and *Dociostaurus tartarus*, is unclear, and these species could be native to Southeastern Europe.

Bradyporidae (Ensifera). A total of 84 species occur in Europe, one of them being possibly alien *to* Europe, *Ephippigerida nigromarginata*, originating from Africa.

Gryllidae (Ensifera). A total of 83 species of gryllids occur in Europe, but only one is an alien species. *Gryllodes sigillatus* is probably native to southwestern Asia and has been spread by commerce to different part of the world. This species is found indoors.

Myrmecophilidae (Ensifera). This small family of crickets contains 11 European species, one having been possibly introduced to Europe, the cryptogenic *Myrmecophilus americanus*. *Myrmecophilus* ant crickets are symbionts associated with ant nests. They are kleptoparasitic and feed on food resources in ant nests and induce ants to regurgitate liquid food. *M. americanus* is associated with an invasive ant species *Paratrechina longicornis.*

Phaneropteridae (Ensifera). Only one alien species, *Topana cincticornis*, has been recorded to be compared with the 149 species of this family native to Europe. This species, of South American origin, has only been observed in France (Morin 2001).

Rhaphidophoridae (Ensifera). This family contains 53 species in Europe. Only one of them is alien to Europe, *Tachycines asynamorus.* This oriental species mostly develops indoors (houses, greenhouses) in Northern Europe but also outdoors during the summer in Southern Europe.

Tettigoniidae (Ensifera). This family contains 221 species in Europe, two of them (namely *Copiphora brevirostris* and *Phlugiola dahlemica*) having been introduced from Central and South America. The latter species was described inhabiting greenhouses in the Botanical Gardens of Berlin (Weidner 1938).

Phasmatodea

Phasmatidae. The family contains only four species in Europe, all of them introduced and occurring in Southern Great Britain. Three of these species (The Prickly Stick Insect, *Acanthoxyla geisovii*, The Unarmed Stick Insect, *Acanthoxyla inermis*, and the Smooth Stick Insect, *Clitarchus hookeri*) arrived from New Zealand with plants, most likely as eggs in the soil (Lee 1993). The last species *Carausius morosus* is native of the Oriental region but was also introduced in Germany (Weidner 1981). Some stick insects used as pets may also have escaped from captivity but we have no data about that.

In conclusion, the only group of polyneopterans with a significant number of introduced species compared to the native European fauna is that of cockroaches (Figure 13.3.1). Blaberidae and Blattidae are represented in Europe only by exotic species non-intentionally introduced by humans.

13.3.3 Temporal trends

The dates of introduction of most alien cockroaches are largely unknown although it is likely that most of these synanthropic species were introduced to Europe long ago, following human movements and trade. For instance, the first record for *Blatta orientalis* dates back to 1500 in a region corresponding at present to the Czech Republic.

Finally, first records in Europe of alien Polyneoptera, excluding four species considered as cryptogenic, were obtained for 21 out of the 33 remaining alien species (64 %). Most of these 21 species were first observed between 1900 and 1975. Interestingly, the mean number of new records per year has not accelerated during the last 200 years, unlike most other groups of arthropods (Figure 13.3.2). On the average, less than one species was newly observed every five years during the period 1900 to 2006.

13.3.4. Biogeographic patterns

Origin of alien species

A region of origin could be traced for 35 (95%) of the alien Polyneoptera introduced to Europe. Central/South America and Asia, with 10 species each (27.0 %), provided equally the greatest part of these alien species followed by Africa (7 spp.; 18.9 %) (Figure 13.3.3). This pattern largely differs from the one observed in most other groups of insects where South America contributes much less to the alien fauna. Indeed, most Blattodea are of tropical origin and generally became sub-cosmopolitan species that occur in buildings and exceptionally outdoors in Europe. Within Orthoptera, most Ensifera also have a tropical origin and several species can presently survive only within greenhouses in Europe. To the contrary, Caelifera are mostly Palaearctic species that naturally occur in areas adjacent to Europe. Alien Isoptera originate from North and South America. Most alien Phasmatodea originate from Australasia and were introduced into England with plants.

Distribution of alien species in Europe

Alien polyneopteran species and families are not evenly distributed throughout Europe and large differences exist between countries (Figure 13.3.4; Table 13.3.3). The number of taxonomists and the intensity of studies and sampling may also have influenced these differences. Little information is available for some central and north-eastern European countries, and consequently these areas appear to host comparatively less alien species.

Germany hosts the largest number of alien Polyneoptera (15 spp.), followed by Denmark (14), Spain (11) and France (10). Most European countries host a low number of introduced species (five or less). No correlation with the country surface area has been found. However, it appears that northern countries in Europe host globally more alien species.

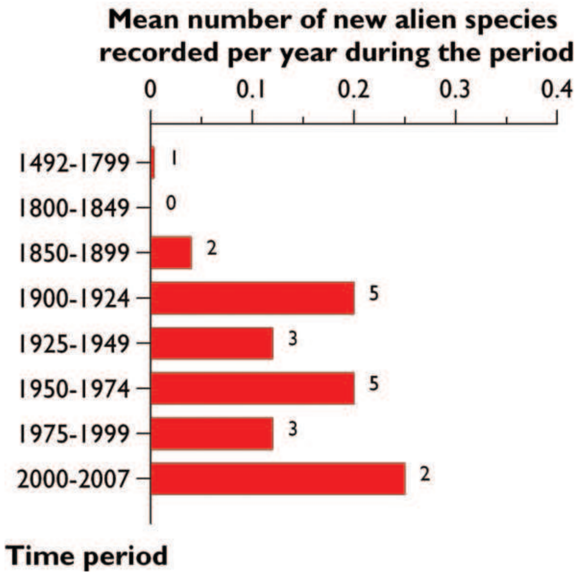

Figure 13.3.2. Temporal changes in the mean number of new records per year of 'Polyneoptera' alien *to* Europe from 1492 to 2006. Cryptogenic species excluded. The number above the bar indicates the number of species introduced.

13.3.5. Main pathways to Europe

The main pathway for introduction of most polyneopteran species alien to Europe is unknown. Where known, most introductions were unintentional. Whilst Blattodea species have followed humans and have long been introduced in Europe probably as stowaways as more recently observed for *Blaberus atropos, Panchlora nivea*, and *Rhyparobia maderae* found within banana shipments (Sein 1923). Some recent invaders also seem to have been introduced through wood transport (Isoptera) or introduction of plant material (Phasmatodea and Ensifera).

Nauphoeta cinerea has been introduced intentionally and only one species (*Euborellia stali*) have been introduced for biological control purposes.

13.3.6. Most invaded ecosystems and habitats

A large proportion of polyneopteran species alien *to* Europe (>75%) are associated with artificial habitats (houses, buildings and greenhouses) and cultivated areas (Figure 13.3.5). The proportion is somewhat lower (>55%) for the species alien to countries within Europe. These results are mostly linked to the strong associations of some Blattodea, Isoptera and Ensifera with humans. Only few species (10 spp.) have yet colonized natural and semi- natural habitats (grasslands, heathland or coastal habitats).

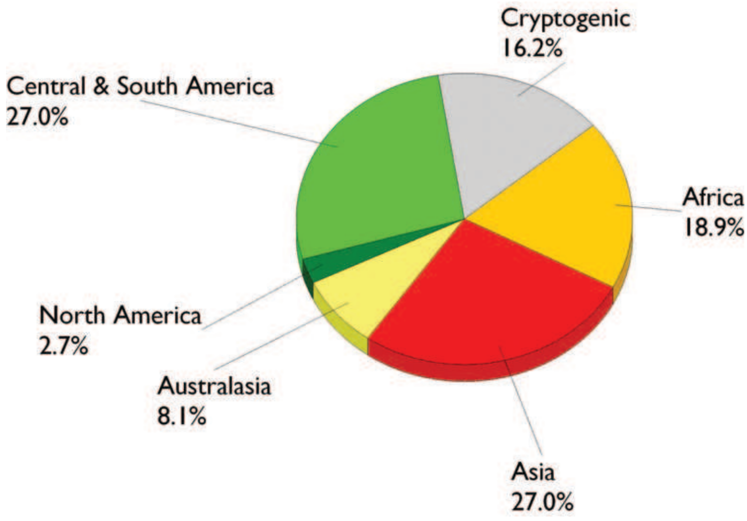

Figure 13.3.3. Origin of the species of Polyneoptera alien *to* Europe.

13.3.7. Ecological and economic impact

While most 'Polyneoptera' species introduced to Europe have only limited ecological or economic impact, two orders are considered as important pests: Blattodea and Isoptera. Blattodea have great medical significance (Baumholtz et al. 1997) and several species of cockroaches represent a potential threat to human health and well-being. These species are the most common household insect pests and there are two areas of concern regarding their potential for causing disease in humans. First, cockroaches are recognized as being an important source of indoor allergens. These allergens are found in their body, saliva and faecal matter. They cause asthmatic reactions in humans and are also implied in skin reactions. In recent studies, a strong association has been found between the presence of cockroaches and increase in the severity of asthma symptoms in individuals who are sensitive to cockroach allergens. Finally, oedema of the eyelids and dermatitis has been attributed to cockroaches.

Second, because of high humidity, high temperature and presence of food, cockroaches normally breed well in houses, grocery stores, restaurants and hospitals. They feed on a variety of foodstuffs (meat, grease, candies, chocolate, cheese, bread and other unprotected materials), regurgitate fluid from their mouth, and deposit faeces on foodstuffs. Because of their movement between waste and food materials, cockroaches can acquire, carry, and directly transfer to food and eating utensils the bacterial pathogens that cause food poisoning, diarrhea (Burgess and Chetwyn 1981), or typhoid. About 40 species of bacteria pathogenic to humans have been naturally found in or on cockroaches. Among them are found, several agents of dangerous infections such as bubonic plague (*Yersinia pestis* (Lehmann and Neumann) van Loghem), dysentery (*Shigella alkalescens* (Andrewes)), diarrhea (*Shigella paradysenteriae* Duval-Sonne), uri-

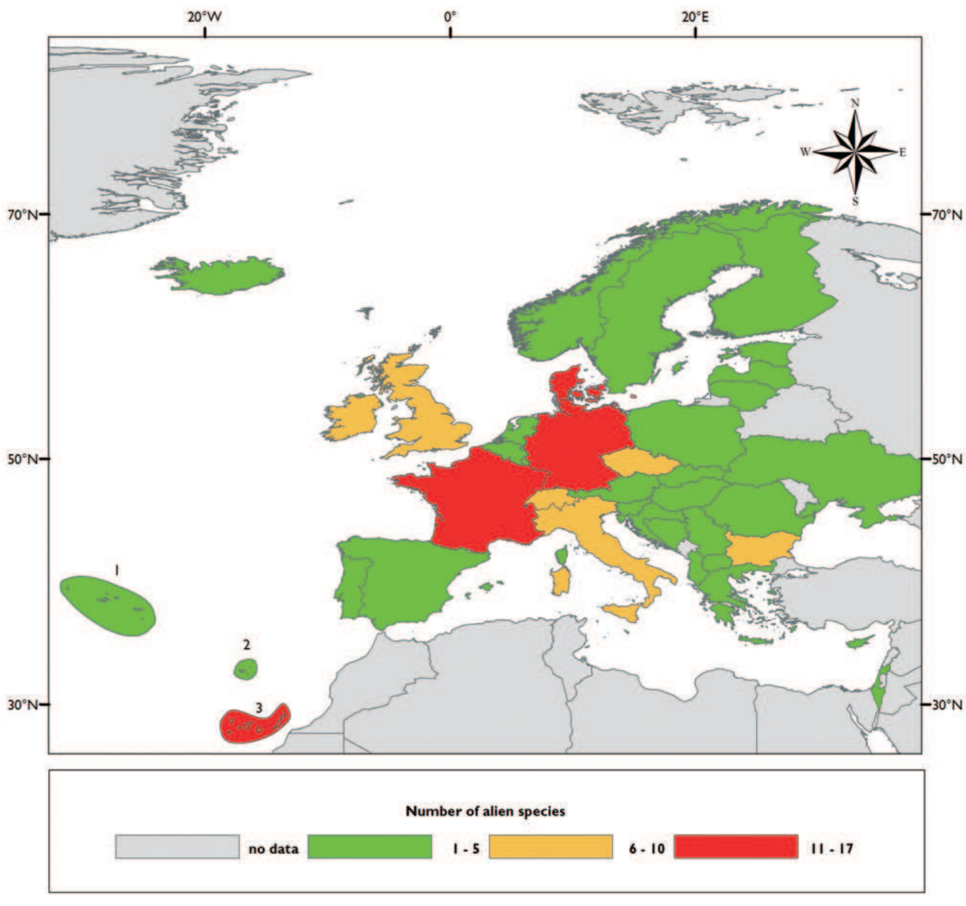

Figure 13.3.4. Comparative colonization of continental European countries and islands by the 'Polyneoptera' species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

nary tract infection (*Pseudomonas aeruginosa* (Schroeter) Migula), abscesses (*Staphylococcus aureus* Rosenbach), food poisoning (*Clostridium perfringens* (Veillon and Zuber) Hauduroy et al, *Escherichia coli* (Migula) Castellani and Chalmers, *Enterococcus faecalis* (Andrewes and Horder) Schleifer and Kilpper-Bälz, *P. aeruginosa*), gastroenteritis (*Salmonella* spp.), typhoid fever (*Salmonella typhi* (Schroeter) Warren and Scott), leprosy (*Mycobacterium leprae* (Hansen) Lehmann and Neumann), and nocardiosis (*Actinomyces* spp). Several species of helminths are also transmitted by cockroaches, among them *Schistosoma haematobium*, *Taenia saginata* Goeze, *Ascaris lumbricoides* L., *Ancylostoma duodenale* (Dubini), and *Necator americanus* (Stiles) (Goddeeris 1980). Helminth eggs have been found naturally occurring in cockroaches, or appear in the faeces (Cochran 1999). Furthermore several virus, protozoa and fungi have been reported as occurring naturally in cockroaches and could also be transmited by these insects. However, proving unequivocally that cockroaches transmit disease to humans remains difficult

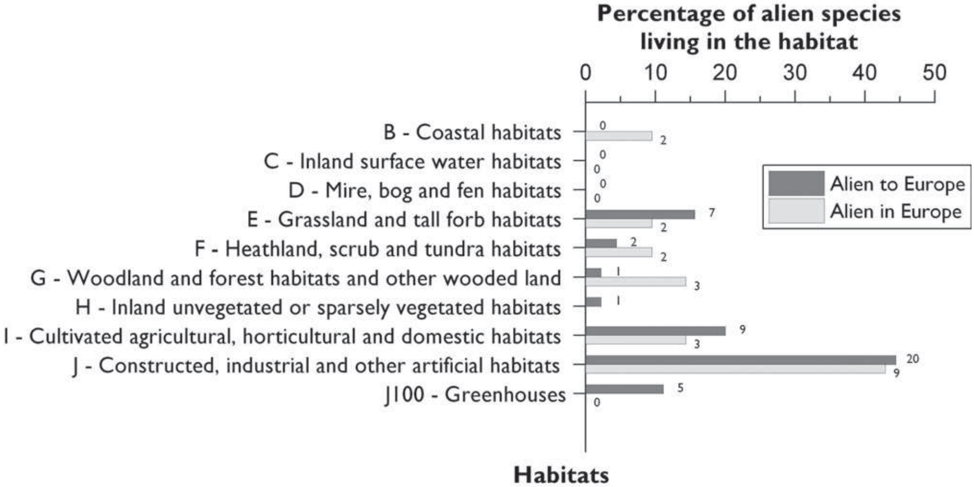

Figure 13.3.5. Main European habitats colonized by the 'Polyneoptera' species alien *to* Europe and alien *in* Europe. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

(Baumholtz et al. 1997). However, costs associated with cockroaches are also linked to their control, either directly or indirectly through the use of pesticides that may facilitate emergence of pathogen resistance to some chemicals. Cockroaches are suspected to be important agents in the transmission of antibiotic resistant microbes in livestock production systems. Livestock production uses antibiotics therapeutically but this facilitates the emergence of resistant bacteria that may subsequently affect the human population. Finally, cockroaches can also damage household items, by eating glue in wallpaper, books, and furniture.

The second group of 'Polyneoptera' with huge economic impact is termites. Termites play a critical ecological and agricultural role and some of them are pests. Some species (e.g. *Cryptotermes brevis*) has been introduced by human activity to almost every part of the world and cause severe damage to wooden structures. *Reticulitermes* Holmgren (Isoptera: Rhinotermitidae) are the major termite pests infesting structures and trees in Europe and the near East (Lohou et al. 1997). This genus contains the most significant termite pests of North America (the *R. flavipes* (Kollar) complex) and Europe (the *R. lucifugus* (Rossi) complex), and significant pest species in Asia (*R. speratus* (Kolbe)). Consequently, some of these species are susceptible to become major pests if they are introduced to Europe in the future. In Germany, *R. flavipes* appears to have been introduced on multiple occasions from USA with pine (*Pinus* spp.) logs (Harris 1962; UNEP 2000; Weidner 1978). This species had caused significant damage and costs for repair and control. The overall cost of treatments against termites in Europe may account for 1 billion euros by 2005 (UNEP 2000) whilst the estimated cost of termite damage could reach \$20 billion annually (Su 2002).

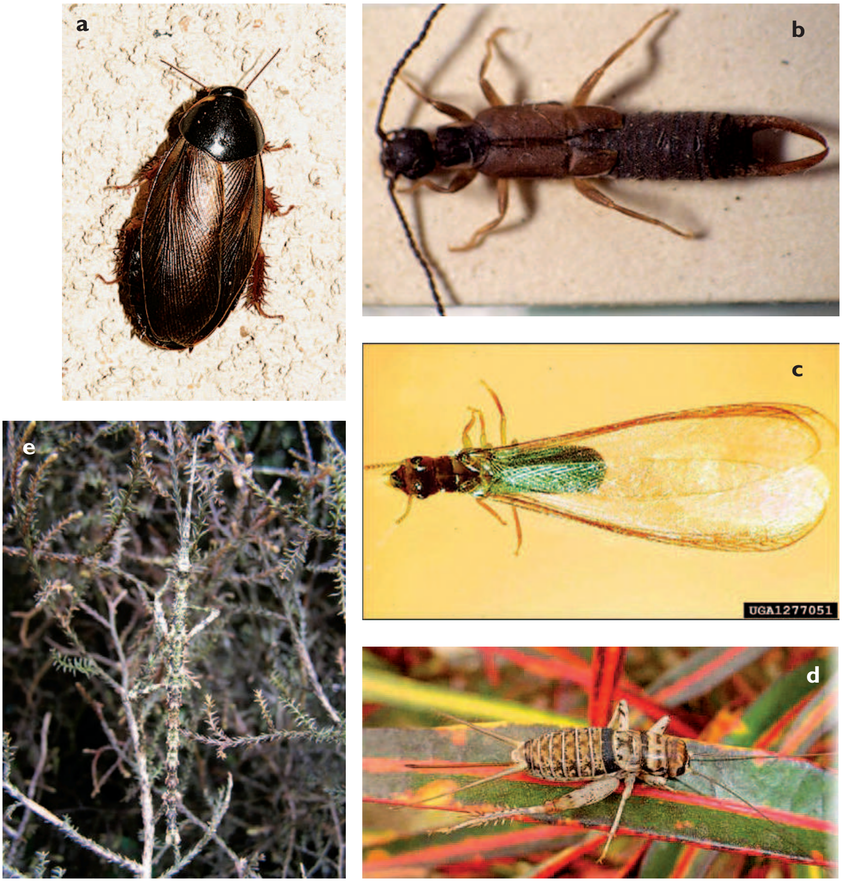

Figure 13.3.6. Some Polyneoptera alien to Europe. **a** Pycnoscelus surinamensis (Blattodea) (Credit : Tom Murray) **b** Nala lividipes (Credit : MNHN Paris) **c** *Cryptotermes brevis* (Isoptera) (Credit : RH Scheffrahn) **d** *Gryllodes sigillatus* (Orthoptera) (Credit : JJ Argoud) **e** late instar nymph of *Ancanthoxyla geisovii* (Phasmatodea). (Credit: R. Hoare).

References

Albouy V, Caussanel C (1990) Dermaptères ou Perce-Oreilles. Faune de France, vol. 75. Paris: Fédération Française des Sociétés de Sciences Naturelles. 245 pp.

Alexander JB, Newton J, Crowe GA (1991) Distribution of Oriental and German cockroaches, *Blatta orientalis* and *Blattella germanica* (Dictyoptera), in the United Kingdom. *Medical and Veterinary Entomology* 5: 395–402.

Asshoff R, Coray A (2003) *Tachycines asynamorus*, *Periplaneta australasiae* and *Pycnoscelus surinamensis* (Ensifera and Blattodea) in the Botanical Garden of Basel, Switzerland. *Mitteilungen der Entomologischen Gesellschaft Basel* 53: 42–55.

Austin JW, Szalanski AL, Ghayourfar R, Kence A, Gold RE (2006) Phylogeny and genetic variation of *Reticulitermes* (Isoptera: Rhinotermitidae) from the eastern Mediterranean and Middle East. *Sociobiology* 47: 873–890.

Austin JW, Szalanski AL, Scheffrahn RH, Messenger MT, Dronnet S*, et al.* (2005) Genetic evidence for the synonymy of two *Reticulitermes* species: *Reticulitermes flavipes* and *Reticulitermes santonensis*. *Annals of the Entomological Society of America* 98: 395–401.

Baumholtz MA, Parish LC, Witkowski JA, Nutting WB (1997) The medical importance of cockroaches. *International Journal of Dermatology* 36: 90–96.

Becker G (1970) Reticulitermes in Mittel und West Europa. *Zeitschrift für Angewandte Entomologie* 65: 268–278.

Becker G, Kny U (1977) Survival and development of the drywood termite *Cryptotermes brevis* (Walker) in Berlin. *Anzeiger für Schaedlingskunde Pflanzenschutz Umweltschutz* 50: 177–179.

Bland RG, Gangwere SK, Morales Martin M (1996) An annotated list of the Orthoptera (sens. lat.) of the Canary Islands. *Journal of Orthoptera Research* 5: 159–173.

Borges PAV, Myles T (2007) Térmitas dos Açores. Resultados do workshop "Medidas para gestão e combate das termitas nos Açores" Principia, Portugal. 125 pp.

Budrys E, Pakalniskis S (2007) The Orthoptera (Insecta) of Lithuania. *Acta Zoologica Lituanica* 17: 105–115.

Burgess NR, Chetwyn KN (1981) Association of cockroaches with an outbreak of dysentery. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 75: 332–333.

Chopard (1922) Faune de France. Orthoptères et Dermaptères. Paris: P. Lechevalier. 200 pp.

Clément J-L, Bagnères AG, Uva P, Wilfert L, Quintana A, et al. (2001) Biosystematics of Reticulitermes termites in Europe: morphological, chemical and molecular data. *Insectes Sociaux* 48: 202–215.

Cochran DG (1999) Cockroaches: their biology, distribution and control. *WHO/CDS/CPC/WHOPES/99.3. World Health Organization Geneva*: 1–83.

Cornwell PB (1968) The Cockroach, Vol. I. London: Hutchinson. 391 pp.

Couvreur J-M, Godeau J-F (2000) Atlas des Orthoptères de la Famenne (Criquets, sauterelles et grillons): Gembloux: Centre de Recherche de la Nature, des Forêts et du Bois. 110 pp.

Decleer K, Devriese H, Hofmans K, Lock K (2000) Voorlopige atlas en "rode lijst" van de sprinkhanen en krekels van België (Insecta, Orthoptera): Werkgroep Saltabel, Rapport van het Instituut voor Natuurbehoud 2000.10, Brussel. 75 pp.

Detzel P (2001) Verzeichnis der Langfühlerschrecken (Ensifera) und Kurzfühlerschrecken (Caelifera) Deutschlands. *Entomofauna Germanica* 5: 63–90.

Ebner R (1958) Nachträge und Ergänzungen zur Fauna der Orthopteroidea und Blattoidea von Österreich. *Entomologisches Nachrichtenblatt der Österreichisch-Schweizerischen Entomologischen Gesellschaft* 10: 6–12.

Essl F, Rabitsch W (Eds) (2002) Neobiota in Österreich. *Umweltbundesamt*, Wien. 432 pp.

Feytaud J (1924) Le termite de Saintonge. *Comptes Rendus de l'Académie des Sciences* 178: 241–244.

Fois F, Cillo D, Piras P, Scano G, Deiana AM (2009). Note sulla recente introduzione di *Shelfordella lateralis* (Blattaria: Blattidae) in Sardegna: attuale distribuzione e considerazioni bioecologiche. Poster, XXII Congresso Nazionale Italiano di Entomologia. Ancona, 15–18 Giugno 2009. Available at [http://www.unica.it/UserFiles/File/News/Fois_NOTE SULLA RECENTE INTRODUZIONE DI SHELFORDELLA LATERALIS[1].pdf]

Fontana P, Buzzetti FM (2003). Nuova segnalazione di *Cryptotermes brevis* (Walker, 1853) in Italia settentrionale (Insecta, Isoptera, Kalotermitidae). *Bollettino del Museo civico di Storia Naturale di Venezia* 54: 35–44.

Gay F (1969) Species introduced by man. In: Krishna K, Weesner F (Eds) Biology of termites, vol I. New York, London: Academic Press, 459–494.

Geiter O, Homma S, Kinzelbach R (2002) Bestandsaufnahme und Bewertung von Neozoen in Deutschland. Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potentiellen Effekten gentechnisch veränderter Organismen. Berlin: Umweltbundesamt pp.

Goddeeris B (1980) The role of insects in dispersing eggs of tapeworms, in particular *Taeniarhynchus saginatum*. I. Review of the literature. *Annales de la Société Belge de Médecine Tropicale* 60: 195–202.

Grandcolas P, Dejean A, Deleporte P (1996) The invading parthenogenetic cockroach: A natural history comment on Parker and Niklasson's study. *Journal of Evolutionary Biology* 9: 1023–1026.

Harris WV (1962) Termites in Europe. *New Scientist* 13: 614–617.

Holst KT (1986) The Saltatoria (Bush-Crickets, Crickets and Grasshoppers) of Northern Europe. Fauna Entomologica Scandinavica, Vol. 16. Leiden, Netherlands; Copenhagen, Denmark: E. J. Brill/Scandinavian Science Press Ltd. 127 pp.

Hubenov Z, Beschovski V, Beshkow S, Kolarov J, Kumanski K, et al. (1998) Insects of Bulgaria, Part 2: Blattodea, Mantodea, Isoptera, Orthoptera, Dermaptera, Embioptera, Megaloptera, Raphidoptera, Neuroptera, Mecoptera, Hymenoptera, Trichoptera, Lepidoptera, and Diptera. Bulgaria's Biological Dversity: Conservaton Status and Needs Assessment, Volumes I and II. Washington, D.C.: Curt Meine. 236–243; 255–257 pp.

Inward DJG, Beccaloni GW, Eggleton P (2007) Death of an order: a comprehensive molecular phylogenetic study confirms that termites are eusocial cockroaches. *Biology Letters* 3: 331–335.

Kleukers RMJC (2002) Nieuwe waarnemingen aan sprinkhanen en krekels in Nederland (Orthoptera). *Nederlandse Faunistische Mededelingen* 17: 87–102.

Lee M (1993) A survey into the distribution of the stick insects of Britain. *Phasmid Studies* 4: 15–23.

Lohou C, Burban G, Clément J-L, Jequel M, Leca. J-L (1997) Protection des arbres d'alignement contre les termites souterrains. L'expérience menée à Paris. *Phytoma* 492: 42–44.

Mielke von U (2001) Nachweis der Australichen Schabe (*Periplaneta australasiae* (Fabricius, 1775)) in Sachsen-Anhalt. *Anzeiger für Schaedlingskunde Pflanzenschutz Umweltschutz* 74: 111–112.

Morin D (2001) Importation accidentelle de *Topana cincticornis* en Gironde (France) et signalisation d'autres espèces du groupe *Topana-Atopana-Pycnopalpa* en Guyane Française (Orthoptera, Tettigoniidae, Phaneropterinae). *Bulletin de la Société Linnéenne de Bordeaux* 29: 27–28.

Morin D (2007) Orthoptères du Languedoc: *Ephippigerida nigromarginata* Lucas, 1849 (Ensifera, Bradyporinae) toujours à Lespignan (France, Hérault). *Bulletin de la Société Linnéenne de Bordeaux* 35: 233–235.

Noël F, Dusoulier F, Barrier Y (2002) *Antaxius spinibrachius* (Fischer, 1853), nouvelle espèce pour la France (Orthoptera, Ensifera). *Bulletin de la Société Entomologique de France* 107: 141–147.

Nunes L, Gaju M, Krecek J, Molero R, Teresa Ferreira M, et al. (2010) First records of urban invasive *Cryptotermes brevis* (Isoptera: Kalotermitidae) in continental Spain and Portugal. *Journal of Applied Entomology* on line first.

Petkovski (2009) National Catalogue (Check List) of Species. Macedonia. *Biodiversity and Protected Areas Consultant (National) within the Project 00058373 "Strenghtenening the Ecological, Institutional and Financial Sustainability of Macedonia's National Protected Areas System*: 1–325.

Presa JJ, García MD, Clemente ME (2007) Catalogue of Orthoptera Caelifera from the Iberian Peninsula and Balearic Islands (Orthoptera: Caelifera). *Journal of Orthoptera Research* 16: 175–179.

Princis K (1947) Beitrag zur Kenntnis der adventiven Blattarien Skandinaviens und Finnlands. *Notulae Entomologicae* 27: 8–13.

Princis K (1966) Orthopterorum Catalogus. pars 8. Gravenhage: Junk pp.

Ragge DR (1965) Grasshoppers, Crickets, and Cockroaches of the British Isles. Chapter 3. London: Frederick Warne & Co. Ltd pp.

Ragge DR (1973) Chapter 10. Dictyoptera. In: Smith KGV (Ed) Insects and other arthropods of medical importance. London: BMNH.

Raineri V, Rey A, Marini M, Zaffagnini V (2001) A new discovery of *Cryptotermes brevis* in Genoa, Italy (Isoptera). *Bollettino della Società Entomologica Italiana* 133: 99–102.

Rehn JAG (1945) Man's uninvited fellow traveler - the cockroach. *The Scientific Monthly* 61: 265–276.

Rey G (1936) Contribution à la faune des Orthoptères de France. *Annales de l'Association des Naturalistes de Levallois-Perret* 22: 77–82.

Scheffrahn RH, Krecek J, Ripa R, Luppichini P (2009) Endemic origin and vast anthropogenic dispersal of the West Indian drywood termite. *Biological Invasions* 11: 787–799.

Scheffrahn RH, Su NY, Chase JA, Forschler BT (2001) New termite (Isoptera: Kalotermitidae, Rhinotermitidae) records from Georgia. *Journal of Entomological Science* 36: 109–113.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Sein FJr (1923) Cucarachas. Puerto Rico Insular Experiment Station. Circular 64. 12 pp.

Stejskal V (1993) Erster Nachweis der Schabe *Periplaneta brunnea* (Burm.) (Blattodea, Blattidae) in Mitteleuropa. *Anzeiger für Schaedlingskunde Pflanzenschutz Umweltschutz* 66: 150–151.

Su NY (2002) Novel technologies for subterranean termite control. *Sociobiology* 40: 95–101.

Tomov R, Trencheva K, Trenchev G, Cota E, Ramadhi A, Ivanov B, Naceski S, Papazova-Anakieva I, Kenis M (2009) *Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia*. Sofia-Moscow: Pensoft, publishers, 112 pp.

Turk SM (1985) Two New-Zealand stick insects naturalized in mainland Cornwall England UK. *Entomologist's Record and Journal of Variation* 97: 129–130.

UNEP, FAO (2000) United Nations Environment Programme and Food and Agriculture Organization. Termite biology and management workshop (Geneva: UNEP).

Uvarov BP (1944) A New Zealand Phasmid (Orthoptera) established in the British Isles. *Proceedings of the Royal Entomological Society of London, B* 13: 94–96.

Vigna Taglianti A (2005) Insecta Dermaptera. In: Ruffo S, Stoch F (Eds) Checklist e distribuzione della fauna italiana. *Memorie del Museo Civico di Storia naturale di Verona, 2 .serie, Sezione Scienze della Vita* 16: 141–142.

Weidner H (1937) Termiten in Hamburg. *Zeitschrift fiir Pflanzenkrankhr* 47: 593.

Weidner H (1938) Die Geradflügler (Orthopteroidea und Blattoidea) der Nordmark und Nordwest-Deutschlands. *Verhandlungen des Vereins für naturwissenschaftliche Heimatforschung zu Hamburg* 26: 25–68.

Weidner H (1978) Die Gelbfussige Bodentermite *Reticulitermes flavipes* (Kollar 1837) in Hamburg (Isoptera). Eine Dokumenation zur Geschichte der angewandten Entomologie in Hamburg. *Entomologische Mitteilungen aus dem Zoologischen Museum Hamburg* 6: 49–100.

Weidner H (1981) Einschleppung von Heuschrecken (Saltatoria und Phasmida) nach Hamburg. *Anzeiger für Schaedlingskunde Pflanzenschutz Umweltschutz* 54: 65–67.

Wetterer JK, Hugel S (2008) Worldwide spread of the ant cricket *Myrmecophilus americanus*, a symbiont of the Longhorn Crazy ant, *Paratrechina longicornis*. *Sociobiology* 52: 157–165.

Table 13.3.1. Blattodea, Isoptera, Orthoptera, Phasmatodea and Dermaptera species alien *to* Europe. List and characteristics. Status: **A** Alien *to* Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 01/03/2010

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
BLATTODEA Blaberidae								
Blaberus atropos (Stoll, 1813)	A	detritovorous	Tropical, subtropical	Unknown	DE, DK	J	With banana	Cornwell (1968), Holst (1986), Princis (1947)
Blaberus parabolicus (Walker,1868)	A	detritovorous	C & S America	Unknown	DK	J		Holst (1986), Princis (1947)
Henschoutedenia flexivitta (Walker, 1868)	A	detritovorous	Africa	Unknown	DE, DK	J	Reared	Holst (1986), Princis (1947)
Nauphoeta cinerea (Olivier, 1789)	A	detritovorous	C & S America	Unknown	CZ, DE, DK, GB	J	Reared for reptile pet food	Cornwell (1968), Šefrová and Laštůvka (2005)
Panchlora fraterna Saussure & Zehntner, 1893	A	detritovorous	C & S America	Unknown	DK	J		Holst (1986), Princis (1947)
Panchlora peruana Saussure, 1864	A	detritovorous	C & S America	1912, DK	DK	J		Holst (1986), Princis (1947)
Phoetalia circumvagans (Burmeister, 1838)	A	detritovorous	Tropical, subtropical	Unknown	ES-CAN	J	in or near human habitations,	Bland et al. (1996)
Phoetalia pallida (Brunner, 1865)	A	detritovorous	Tropical, subtropical	Unknown	DK, ES-CAN	J	In or near human habitations,	Princis (1947)
Pycnoscelus surinamensis (Linnaeus, 1767)	A	detritovorous	Asia-Tropical	1950, CZ	CH, CZ, ES-CAN, FR, GB, IE, IL, IS, PL, PT-AZO, PT-MAD	J1	Tropical and subtropical moist places	Asshoff and Coray (2003), Chopard (1922), Cornwell (1968), Šefrová and Laštůvka (2005)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Rhyparobia maderae (Fabricius, 1781)	A	detritovorous	Africa	Unknown	DE, ES, ES-CAN, FR-COR	J, I1	Food stores indoors, outdoors prefers to live in sugarcane fields, as well as palms, guava, and bananas growing next to the fields; fond of bananas and grapes.	Cochran (1999)
BLATTODEA Blatellidae								
Nyctibora laevigata (Beauvois, 1805)	C	detritovorous	Cryptogenic	Unknown	DK	J		Princis (1947)
Supella longipalpa (Fabricius, 1798)	A	detritovorous	Africa	1945, DE	AL, CH, CZ, DE, DK, ES-CAN, FI, FR, GB, GR-SEG, GR, HU, IE, IL, IT-SAR, IT-SIC, IT, RO, SK	J1	Omnivorous, synanthropic, warm and dry habitats	Chopard (1922), Ragge (1973), Rehn (1945), Šefrová and Laštůvka (2005)
BLATTODEA Blattidae								
Blatta orientalis Linnaeus, 1758	C	detritovorous	Cryptogenic	1500, CZ	AL, AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES-CAN, FI, FR-COR, FR, GB, GR-SEG, GR, HR, AT, HU, IE, IL, IS, IT-SAR, IT-SIC, IT, LV, LT, LU, MT, NL, NO, PL, PT-AZO, PT-MAD, PT, RO, SE, SI, SK, SE, UA	J1, J6	Omnivorous, synanthropic; decaying organic matter (sewers, drains, damp basements, porches, and other damp locations), outdoors in bushes, under leaf groundcover and mulch	Alexander et al. (1991), Šefrová and Laštůvka (2005)
Neostylopyga rhombifolia (Stål, 1861)	C	detritovorous	Cryptogenic	Unknown	CZ	G, I2	Omnivorous, synanthropic, warm climate; not cold tolerant, moist conditions	Šefrová and Laštůvka (2005)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Periplaneta americana (Linnaeus, 1758)	A	detrito-vorous	Africa	1600, IT	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES-CAN, ES, FI, FR, GB, GR-CRE, GR-NEG, GR-SEG, GR, HR, AT, HU, IE, IL, IS, IT-SAR, IT-SIC, IT, LV, LT, LU, MT, NO, PL, PT-AZO, PT-MAD, PT, SI, SK, SE	J1, H1, J100	Omnivorous, synanthropic, warm climate; not cold tolerant, moist conditions	Princis (1966), Ragge (1945), Šefrová and Laštůvka (2005)
Periplaneta australasiae (Fabricius, 1775)	A	detrito-vorous/ phyto-phagous	Asia-Tropical	1927, DE	AT, CH, CZ, DE, DK, ES-CAN, FI, FR, GB, AT, IE, IS, IT-SAR, IT-SIC, IT, PL, SK, SE	J1, J100	Omnivorous, synanthropic, warm climates, moist, eat plants outdoors	Asshof and Coray (2003), Mileke (2001), Princis (1966), Ragge (1945), Šefrová and Laštůvka (2005)
Periplaneta brunnea Burmeister, 1838	A	detrito-vorous	Africa	Unknown	CZ, ES-CAN, PT-MAD, SK, SE	J1	Near human habitats in cold climate; mainly outdoors, under the bark of trees and in sewers in native and warm	Šefrová and Laštůvka (2005), Stejskal (1993)
Shelfordella lateralis (Walker, 1868)	A	detrito-vorous	Central Asia	2009, IT-SAR	IT-SAR	J	Herbaceous places near human habitats, along streets.	Fois et al. (2009)
DERMAPTERA Anisolabididae								
Euborellia stali (Dohrn, 1864)	A	parasitic/ predator	Asia	2002, IT	IT	I	Sugarcane field in native range	Vigna- Taglianti (2005)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
DERMAPTERA Labiduridae								
Nala lividipes (Dufour, 1828)	A	parasitic/ predator	Tropical, subtropical	1915, IT-SIC	ES-BAL, ES-CAN, ES, FR, IT-SAR, IT-SIC, IT, PT	I, J	Granivore, predator, Economic pest of agricultural crops; hosts: Beta vulgaris (beetroot), Glycine max (L.) (soybean), Glossipium sp.(cotton), Helianthus annuus L. (sunflower), Sorghum sp. (sorghum)	Albouy and Caussanel (1990)
ISOPTERA Kalotermitidae								
Cryptotermes brevis (Walker, 1853)	A	phyto-phagous	C & S America	1993, DE	DE, ES-CAN, GB, IT, PT-AZO, PT	J	Soil, buildings	Becker and Kny (1977), Fontana and Buzzetti (2003), Gay (1969), Nunes et al. (2010), Raineri (2001), Scheffrahn et al. (2001)
ISOPTERA Rhinotermitidae								
Reticulitermes flavipes (Kollar, 1837)	A	phyto-phagous	North America	1934, DE	AT, DE, FR	J	Soil, buildings	Austin et al. (2005, 2006), Clément et al. (2001), Feytaud (1924), Weidner (1937)
ORTHOPTERA Acrididae								
Dociostaurus tartarus Shchelkanovtsev, 1921	A	phyto-phagous	Asia	1962, BG	BG	E		Hubenov et al. (1998)
Locusta migratoria (L, 1758)	A	phyto-phagous	Africa	1886, FR	AL, BG, DK, FR, FR-COR, HU, LV, PT	F3	Migration ?	Budrys and Pakalniskis (2007), Presa et al. (2007), Rey (1936)

Families *Species*	Status	Regime	Native range	First Record in Europe	Invaded countries	Habitat	Host	References
Notostaurus albicornis (Eversmann, 1848))	A	phyto-phagous	Asia	1964, BG	BG	E		Tomov et al. (2009)
Ramburiella turcomana (Fischer von Waldheim, 1846)	A	phyto-phagous	Asia	1962, BG	BG, MK	E		Petkovski (2009)
ORTHOPTERA Bradyporidae								
Ephippigerida nigromarginata (Lucas, 1849)	A	unknown	Africa	1953, FR	FR, IT-SIC	F6	?	Morin (2007)
ORTHOPTERA Gryllidae								
Gryllodes sigillatus Walker 1869	A	detrito-vorous	Asia	Unknown	DE, GB, NL	J100		Geiter et al. (2002), Weidner (1981)
ORTHOPTERA Myrmecophilidae								
Myrmecophilus americanus Saussure 1877	C	detrito-vorous	Cryptogenic	Unknown	DE	U	Ant nests	Geiter et al. (2002), Wetterer and Hugel (2008)
ORTHOPTERA Phaneropteridae								
Topana cincticornis (Stal, 1873)	A	detrito-vorous	C & S America	1991, FR	FR	U		Morin (2001)
ORTHOPTERA Raphidophoridae								
Tachycines asynamorus Adelung, 1902	A	detrito-vorous	Asia	1892, DE	AT, BG, CH, DE, DK, EE, FR, GB, AT, IE, IT, LV	J100	Omnivorous, greenhouses and botanical gardens	Asshoff and Coray (2003), Detzel (2001), Geiter et al. (2002), Weidner (1981)
ORTHOPTERA Tettigoniidae								
Copiphora brevirostris Stäl, 1873	A	phyto-phagous	C & S America	Unknown	DE	J100	Greenhouses	Detzel (2001)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Phlugiola dahlemica Eichler, 1938	A	phyto-phagous	C & S America	1924, DE	DE	I2	Botanic garden	Weidner (1938)
PHASMATODEA Phasmatidae								
Acanthoxyla geisovii (Kaup, 1866)	A	phyto-phagous	Australasia	1908, GB	GB	I2, E5	Bramble, Eucalyptus, Cupressus	Lee (1993), Turk (1985), Uvarov (1944)
Acanthoxyla inermis Salmon, 1955	A	phyto-phagous	Australasia	1981, GB	GB	I2, E5	Rose, Bramble, Eucalyptus	Lee (1993), Turk (1985)
Carausius morosus (Sinéty, 1901)	A	phyto-phagous	Asia	Unknown	DE, GB	I2, E5	Privet, Ivy, Hawthorn, Pyracantha, Bramble, Rose	Lee (1993), Weidner (1981)
Clitarchus hookeri (White, 1846)	A	phyto-phagous	Australasia	1900, GB	GB, IE	I2, E5	Bramble, Eucalyptus, Guava	Lee (1993)

Table 13.3.2. Blattodea, Isoptera, Orthoptera, Phasmatodea and Dermaptera species alien *in* Europe. List and characteristics. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 01/03/2010.

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
DERMAPTERA Anisolabidae								
Anisolabis maritima (Bonelli, 1832)	E	parasitic/ predator	Mediterranean region ? (Cosmo-politan)	Unknown	DE, DK, GB, IL	B, J1, J6	Waste, algae in coastal areas	Albouy and Caussanel (1990)
DERMAPTERA Carcinophoridae								
Euborellia annulipes (Lucas, 1847)	E	parasitic/ predator, phyto-phagous	Mediterranean region ? (Cosmo-politan)	1837, IT	CZ, DE, DK, ES-BAL, ES-CAN, ES, FR, GB, GR-CRE, GR-SEG, GR, HR, IL, IT-SAR, IT-SIC, IT, MT, NL, PT-AZO, PT-MAD, PT, UA	B, J1, J6	Omnivorous, on plant and animal material; minor nuisance in gardens	Albouy and Caussanel (1990)
DERMAPTERA Labidae								
Forficula smyrnensis Serville, 1838	E	unknown	Mediterranean region	1882, FR-COR	FR-COR, FR	F9, J6	Under plane bark, along Adour river	Albouy and Caussanel (1990)
ISOPTERA Kalotermitidae								
Kalotermes flavicollis (Fabricius 1793)	E	phyto-phagous	Mediterranean region	2005, PT-AZO	PT-AZO	G, J	Dry wood, forests, buildings	Borges and Myles (2007)
ISOPTERA Rhinotermitidae								
Reticulitermes lucifugus (Rossi 1792)	E	phyto-phagous	Mediterranean region	Unknown, DE	DE	J	Soil, buildings	Becker (1970)
ORTHOPTERA Acrididae								
Anacridium aegyptium (Linnaeus 1764)	E	phyto-phagous	Mediterranean region	Unknown	AL, DE, DK	F6		Weidner (1981)

Families *Species*	**Status**	**Regime**	**Native range**	**First Record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
ORTHOPTERA Meconematidae								
Meconema meridionale Costa, 1860	E	phyto-phagous	Mediterranean region	1900, AT	AT, BE, GB, AT, NL	I2	Urban parks; highway parkings	Couvreur and Godeau (2000), Decleer et al. (2000), Kleukers (2002)
ORTHOPTERA Phaneropteridae								
Leptophyes punctatissima (Bosc, 1792)	E	phyto-phagous	Southern Europe	1956, AT	AT	U	Gardens	Ebner (1958), Essl and Rabitsch (2002)
ORTHOPTERA Rhaphidophoridae								
Dolichopoda bormansi Brunner von Watt., 1882	E	detrito-vorous	Mediterranean region	Unknown	DE	G3, G4	Cliffs in pine stands (*pinus nigra*)	Geiter et al. (2002)
Troglophillus neglectus (Kraus, 1879)	E	detrito-vorous	Mediterranean region	1998, CZ	CZ	J6	Cave, cellars	Šefrová and Laštůvka (2005)
ORTHOPTERA Tettigoniidae								
Antaxius spinibrachius (Fischer, 1853)	E	detrito-vorous	Mediterranean region	1999, FR	FR	J	Slate quarry	Nöel et al. (2002)
PHASMATODEA Bacillidae								
Bacillius rossius (Rossi, 1788)	E	phyto-phagous	Mediterranean region	Unknown	GB	I2, E5	Bramble, rose	Lee (1993)
Clonopsis gallica (Charpentier, 1825)	E	phyto-phagous	Mediterranean region	Unknown	GB	I2, E5	Bramble, Broom	Lee (1993)

Table 13.3.3. Number of alien 'polyneoptera' per European country.

Countries	N	Countries	N
Germany mainland	17	Sweden	4
Denmark	14	Estonia	3
Spain Canary islands	11	Greece South Aegean	3
France mainland	11	Greece mainland	3
Great Britain	10	Spain mainland	3
Czech Republic	8	Belgium	2
Italy mainland	8	Croatia	2
Bulgaria	7	France Corsica	2
Ireland	7	Lithuania	2
Italy Sicily	6	Luxemburg	2
Switzerland	6	Malta	2
Italy Sardinia	6	Norway mainland	2
Austria	5	Netherlands	2
Portugal mainland	5	Romania	2
Slovakia	5	Slovenia	2
Albania	4	Bosnia	1
Finland mainland	4	Cyprus	1
Hungary	4	Greece Crete	1
Iceland	4	Greece North Aegean	1
Israel	4	Macedonia	1
Latvia	4	Serbia	1
Poland	4	Spain Balearic islands	1
Portugal Azores	4	Ukraine	1
Portugal Madeira	4		

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Lice and Fleas (Phthiraptera and Siphonaptera) Chapter 13.4

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Abstract

A total of 31 Phthiraptera species alien *to* Europe are listed. They include 24 chewing lice and seven sucking lice of 12 different families. The families Goniodidae (Ischnocera) and Menoponidae (Amblycera) largely dominate the alien entomofauna of chewing lice. Asia is the major supplier of alien Phthiraptera which are mostly associated with poultry farming, game birds, guinea pigs and invasive alien mammals. The recent period did not show any acceleration in alien arrival in Europe. Alien fleas include six species in the families Pulicidae and Ceratophyllidae. Three of them are primarily associated with rats and are capable of transmiting major human diseases such as the bubonic plague and the murine typhus.

Keywords

Phthiraptera, lice, flea, Siphonaptera, alien, Europe

13.4.1. Introduction

Phthiraptera (lice) and Siphonaptera (fleas) are obligate ectoparasitic insects of birds and mammals, including humans. Some are of high importance for human and animal health because they cause itches and skin infection, and transmit serious diseases, e.g. the head louse (*Pediculus capitis* De Geer), the crab louse (*Phtirus pubis* (*L.*)), the cat flea (*Ctenocephalides felis felis* (Bouché)), the rat flea (*Xenopsylla cheopis* (Rothschild)) or the human flea (*Pulex irritans* L.). Although many of these are of unknown origin, they are probably allochtonous in Europe, having arrived in ancient times with their hosts (Mey, 1988; Beaucournu and Launay, 1990). Thus, *Pulex irritans* was shown to have been present in Europe since the Bronze Age at least, having been found in remains of lake dwellings in the French Jura, dating back to 3100 B.C. (Yvinec et al 2000).

Only the species considered as possibly neozoans*, i.e. 27 lice and six fleas, were originally included in the DAISIE database. Four further species have subsequently been added to the list of alien species and this review is therefore based on 31 species.

Although a large part of these alien species were recorded in Europe for the first time at the end of the 19th century, many probably came much earlier; the exact date of arrival remaining unclear in nearly all cases.

13.4.2 Phthiraptera

Lice are *exopterygotes** of birds and mammals. Most species are host-specific but others are rather polyphagous. They spend their entire life on their host animal, feeding on epidermal tissue debris, parts of feathers, blood or sebaceous secretions. Until recently, they were divided into two orders, Anoplura (sucking lice) and Mallophaga (chewing lice), but they are presently grouped into a single order, Phthiraptera (Barker et al 2003; Price et al 2003). The order Phthiraptera comprises about 5,000 described species present in four sub-orders, Anoplura (543 spp. on mammals), Amblycera (ca. 1360 spp. on birds, mammals and marsupials), Ischnocera (ca. 3080 spp. on birds and mammals) and Rhynchophthirina (3 spp. on elephants and warthogs), this latter group being not present in Europe (Smith 2003).

A total of 31 Phthiraptera species alien *to* Europe have been listed here, including 16 species known to be of exotic origin and 14 cryptogenic species, to be compared to the 691 species considered as native to Europe included in Fauna Europaea (Mey 2005). They include 24 chewing lice belonging to 8 different families and 7 sucking lice belonging to 4 different families (Table 13.4.1). Three of the families have no representatives in Europe (Gliricolidae, Gyropidae, Trimenoponidae; all in the Amblycera suborder). The families Goniodidae (Ischnocera) and Menoponidae largely dominate the alien entomofauna (Figure 13.4.1). In a number of families, the arrival of aliens has largely modified the composition of the total entomofauna currently present in Europe.

In contrast to the trends reported in other arthropod groups, the majority of the alien lice were first observed in Europe during the 18th and 19th century (18 species out of 31- 58.1%), although they probably arrived much earlier with their animal host, in most cases a domestic species. The recent period did not show any acceleration in alien arrival in Europe with only 4 species (12.9 % of the total species) newly observed during the period 1975- 2007. Eight out the 17 alien species of known exotic origin came from Asia (47.0 %), with earlier arrival dates than those from North America (4 spp.; 23.5 %) or South America (4 spp.).

Several chewing lice of cryptogenic origin are important pests of poultry farming, in particular *Menopon gallinae, Goniocotes gallinae* and *Eomenacanthus stramineus*

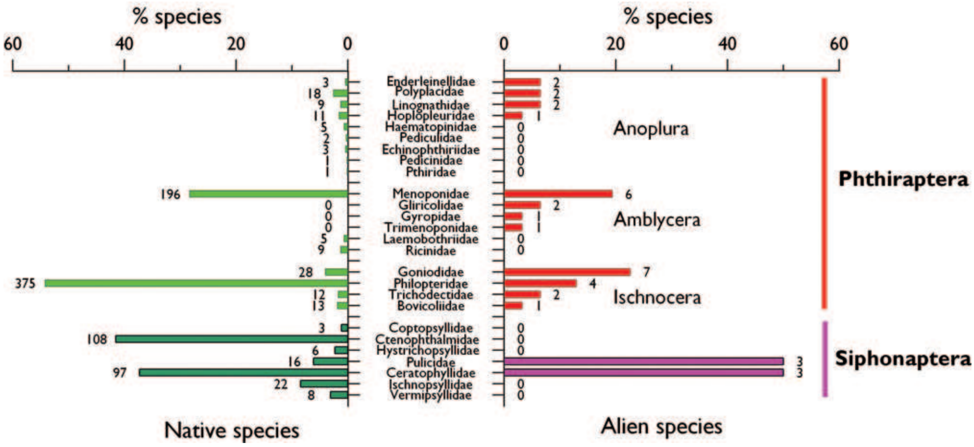

Figure 13.4.1. Relative importance of the Phthiraptera and Siphonaptera suborders and families in the alien and native fauna in Europe. Families of Phthiraptera are presented per suborder in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of species observed per family.

(Sychra et al 2008). Other species parasitize pheasants (*Phasianus* spp.) and came with their host from Asia, such as *Goniocotes chrysocephalus, Lagopoecus colchicus, Lipeurus maculosus, Uchida phasiani, Zlotorzyckella colchici* (Kopocinski et al 1998). Chewing lice parasitising mammals in Europe are listed in Mey (1988). Some species are known to be of alien origin, such as the three South American species, *Gyropus ovalis*, *Gliricola porcelli* and *Trimenopon hispidum,* arriving in Europe with guinea pigs (*Cavia porcellus* L.) and causing scratching, loss of hair, and scabs to domestic and laboratory animals. Other species worth mentioning are the cryptogenic dog louse, *Trichodectes canis,* and the sheep louse, *Bovicola ovis*, which cause pruritus and skin infections such as eczema to their host animal. Finally, a few species are associated with invasive alien mammals, such as the South American *Pitrufquenia coypus* on coypu (*Myocastor coypus* (Molina)); (Laurie 1946; Newson and Holmes 1968) and the North American *Trichodectes* (*Stachiella*) *octomaculatus* on raccoon (*Procyon lotor* (L.)); (Hellenthal et al 2004).

Only seven sucking lice of four families (Enderleinellidae, Hoplopleuridae, Linognathidae, and Polyplacidae) are considered Neozoans in Europe (Table 13.4.1). The Asian *Polyplax spinulosa* (spined rat louse) causes hair loss and pruritus to wild and domestic rats (*Rattus* spp.). The cryptogenic species *Linognathus stenopsis* and *Haemodipsus lyriocephalus* parasitize goats (*Capra hircus* L.) and hares (*Lepus europaeus* Pallas), respectively. According to Durden and Musser (1994), another *Haemodipsus* species, *H. setoni* Ewing associated with *Lepus* spp. in North America is possibly an introduced species in Eurasia (this species has not been included here). Three species have been introduced to Europe with their Sciuridae host from either North America (*Enderleinellus longiceps* and *Hoplopeura sciuricola* with grey squirel, *Sciurus carolinensis* Gmelin; Britt and Molineux 1979) or Asia (*Enderleinellus tamiasis* with Siberian chipmunk, *Tamia sibiricus* (Laxmann); Beaucornu et al 2008). *Solenopotes muntiacus* has also been

Figure 13.4.2. Alien Phthiraptera (Anoplura)**.** *Solenopotes muntiacus* female from Muntjac deer, *Muntiacus muntjak* (Credit: British Museum of Natural History, London)

introduced from Asia to Great Britain with muntjac deers, *Muntiacus reevesi* (Ogilby) (Dansie et al 1983).

In addition, *Haemodipsus ventricosus* (Denny) which lives on rabbits (*Oryctolagus cuniculus* L.) can be considered as alien *in* Europe, originating, as its host, from the Iberic pensinsula (Durden and Musser 1994).

13.4.3 Siphonaptera

Fleas are holometabolous insects whose adults must feed on blood of mammals and birds in order to reproduce. Larvae feed on organic matter, often in the host's nest. In the DAISIE database, six fleas are listed as alien to Europe, including 5 species known to be of exotic origin and 1 cryptogenic species, in comparison to the 260 species considered as native to Europe (Soledad Gomez Lopez 2005) (Table 13.4.1). The aliens belong equally to two families, Pulicidae and Ceratophyllidae, whereas the latter family largely dominates the native entomofauna. Three of these fleas have rats as their main host (Beaucornu and Launay, 1990). The tropical rat flea, *Xenopsylla cheopis*, probably originates from the Nile area (Beaucornu 1999). It became synanthropic in most of Southern Europe where it could not survive before because of large temperature variations between summer and winter within human habitats (Beaucornu 1999). *X. brasiliensis,* originates from tropical Africa and invaded the Canary islands (Beaucornu and Launay, 1990); it has also been

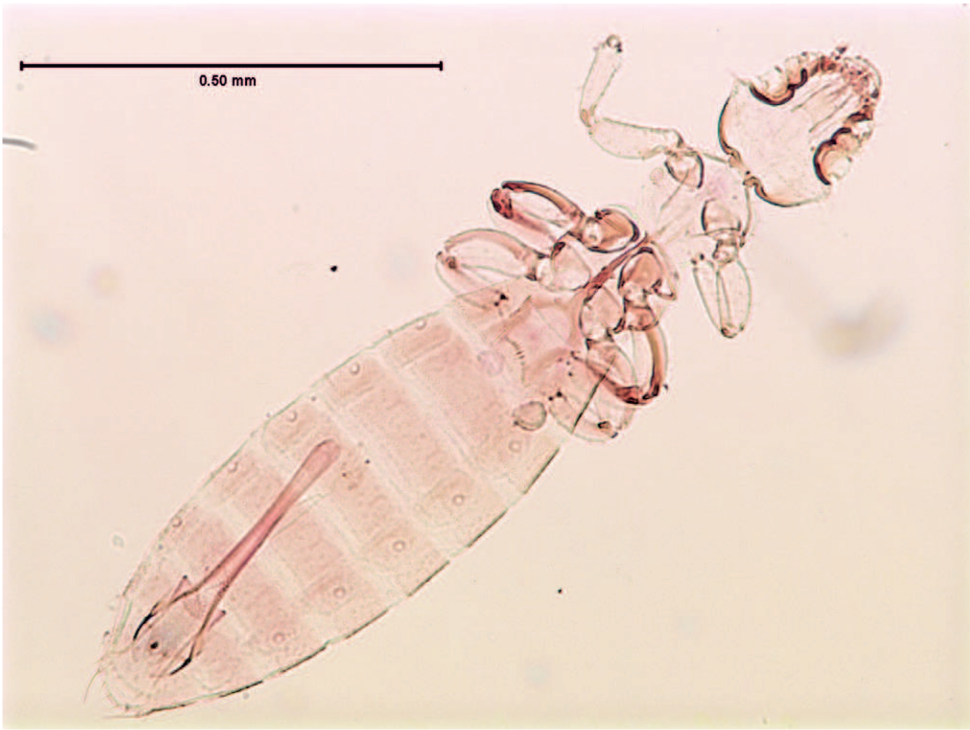

Figure 13.4.3. Alien Phthiraptera (Amblycera). *Gliricola porcelli* male from guinea pig, *Cavia porcellus* (Credit: British Museum of Natural History, London)

found sporadically in port areas and elsewhere, e.g. it was recorded from Wales in the 1950s (Hopkins and Rotschild 1953). The third species, *Nosopsyllus fasciatus,* is a temperate species from Asia. Rat fleas are also able to feed on other mammals, including humans, to which they can transmit the bubonic plague by carrying the bacteria *Yersinia pestis* (Audouin-Rouzeau, 2003). *Xenopsylla cheopis* is also a vector of another human disease, the murine typhus fever caused by the bacteria *Rickettsia typhi* (Beaucournu and Launay, 1990). The North American species *Orchopeas howardi* is found on the grey squirrel (*Sciurus carolinensis*), an invasive rodent in Europe (Keymer, 1983).

In addition, a rabbit flea, *Spilopsyllus cuniculi* (Dale), can be considered as alien *in* Europe, probably originating with its host from the Iberian Peninsula. It has invaded a large part of Western and Central Europe (Soledad Gomez Lopez 2005). It is the principal vector of rabbit myxomatosis, a disease which was deliberately introduced from South America into Europe in 1952 in order to control rabbit populations (Beaucournu and Launay, 1990). Another flea of Mediterranean origin, the ceratophyllid *Nosopsyllus* (*Nosopsyllus*) *londinensis londinensis* (Rothschild), hosted by mice (*Mus domesticus*) and rats (*Rattus* spp.), has been introduced in urban habitats in Belgium, Switzerland, Great Britain and in the Oceanic islands (Madeira, The Azores) (Rothschild 1903; Smit 1957; Mahnert 1974; Beaucournu and Launay, 1990).

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References

Anonymous (1994) *Orchopeas howardi* reported from S.E. London. *British Journal of Entomology and Natural History* 7: 102–109.

Audouin-Rouzeau F (2003) *Les Chemins de la Peste - Le Rat, la Puce et l'Homme*. Rennes, France : Presses universitaires de Rennes.

Barker SC, Whiting M, Johnson KP, Murrell A (2003) Phylogeny of the lice (Insecta: Phthiraptera) inferred from small subunit rRNA. *Zoologica Scripta* 3: 407–414.

Beaucornu JC (1972) Sur quelques ectoparasites (Siphonaptères, anoploures et nyctéribies) du Portugal. *Anais da Escola Nacional de Saúde Pública e de Medicina Tropical* 6: 65–71.

Beaucornu JC (1976) Notes sur les Ceratophyllidae (Siphonaptera) de la faune française, parasites de mammifères. *Annales de la Société Entomologique de France* (N.S.) 12: 199–213.

Beaucornu JC (1978) Enquête sur les arthropodes vecteurs dans la Péninsule Ibérique: Liste des Siphonaptères. *Médecine et maladies infectieuses* 8: 121–124.

Beaucornu JC (1999) Diversité des puces vectrices en fonction des foyers pesteux. *Bulletin de la Société de pathologie exotique* 92: 419–421.

Beaucornu JC, Alcover JA (1984) Siphonaptera from Small Terrestrial Mammals in the Pityusic Islands. In Kuhbier H, Alcover JA, d'Arellano Tur G (Eds), *Biogeography and Ecology of the Pityusic Islands*. The Hague: Dr. W. Junk Publisher, 377–392.

Beaucornu JC, Aeschlimann A (1985) Une Puce nouvelle pour la region Paléarctique Occidentale : Présence en Suisse de *Callopsylla gemina* (Ioff, 1946) (Siphonaptera: Ceratophyllidae). *Bulletin de la Société Neuchâteloise des Sciences Naturelles* 108: 55–62.

Beaucournu JC, Launay H (1977) Présence en France d'une Xenopsylla selvatique *X. cunicularis* Smit, 1957 (Siphonoptera, pulcidae) parasite du lapin de garenne. Bulletin de la Société de Pathologie Exotique 70: 299–301.

Beaucournu JC, Launay H (1990) Les puces (Siphonaptera) de France et du Bassin méditerranéen occidental. *Faune de France* 76. Paris: Fédération Française des Sociétés de Sciences Naturelles. 548 pp.

Beaucournu JC, Pascal M (1998) Origine biogéographique de *Nosopsyllus fasciatus* (Bosc, 1800) (Siphonaptera - Ceratophyllidae) et observations sur son hôte primitif. *Biogeographica* 74: 125–132.

Beaucournu JC, Pisanu B, Chapuis JL (2008). *Enderleinellus tamiasis* Fahrenholz, 1916 (Anoplura: Enderleinellidae), espèce importée, implantée et nouvelle pour la faune de France. *Parasite* 15: 75–78.

Beaucournu JC, Valle M, Launay H (1981) Siphonaptères d'Italie Méridionale ; description de cinq nouveaux taxa. *Rivista di Parassitologia* 42: 483–505.

Bernard L, Dounet G, Jaujou (1947) Une épidémie de Pest bubonique à Ajaccio (1945). *Recueil des Travaux de l'Institut National d'Hygiène de Paris* 3: 355–375

Bordeau W (2008) Phtiriose à *Gliricola porcelli* chez le cobaye: l'association imidaclopride-moxidectine est efficace. *Sciences et Pratique* 999, 13–19.

Britt D, Molyneux DH (1979) Parasites of Grey Squirrels in Cheshire, England. *The Journal of Parasitology* 65: 408.

Broekhuizen S (1971) On the occurrence of hare lice, *Haemodipsus spp*. (Anoplura: Hoplopleuridae) on hares, *Lepus europaeus*, in the Netherlands. *Zeitschrift für Parasitenkunde* 36: 158–168.

Büttiker W, Mahnert V (1978) Vorläufige Liste der Anoplura (Insecta der Schweiz). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 51: 299–306.

Cartana Castella P, Gil Collado J (1934) *Estudio de la ratas y de sus ectoparasitos en ocasion del brote epidemico de peste en Barcelona en 1931*. Madrid: Commission Permanente de Investigaciones sanitarias. 316 pp.

Clay T (1938) A revision of the genera and species of Mallophaga occuring on gallinaceous hasts. Part. 1. *Lipeurus* and related genera. *Proceedings of the Zoological Society of London (D)* 108: 109–204.

Cummings BF (1916) Studies on the Anoplura and Mallophaga, being a report upon a collection from the Mammals and Dirds in the Society's gardens. *Proceedings of the Zoological Society of London*: 253–295.

Dale CW (1878), *The History of Glanville's Wootton in the county of Dorset, including its zoology and botany*. London. 392 pp.

Dansie O, Cooke A, Farrell L (1983) *Muntjac and Chinese Water Deer*. London: The British Deer Society. 43pp.

Denny H (1842) *Monographia Anoplurorum Britanniae, or an Essay on the British species of parasitic insects belonging to the order Anoplura of Leach*. London: Bohn. 263 pp.

Dlabola J (Ed.) (1977) *Check-list of Czechoslovak Insects I*. Praha: Národní Muzeum. 160 pp.

Donisthorpe H (1925) Insects in the nest of the grey squirrel. *Entomologist's Record* 37: 163.

Durden LA, Musser GG (1994) The sucking lice (Insecta, Anoplura) of the world: a taxonomic checklist with records of mammalian hosts and geographical distributions. *Bulletin of the American Museum of Natural History* 218: 1–90.

Fauna Italia (2003) *Families Anoploura, Mallophaga, Siphonaptera*. available at [http://www.faunaitalia.it/checklist/invertebrates/families]. last update December 3, 2003.

Galli- Valerio B (1900) Sur les puces d'*Arvicola nivalis*. *Archives de Parasitologie* 3: 96–101

Geiter O, Homma S, Kinzelbach R (2002) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltbundesamt 25: 1–173.

Giles GM (1905), *Pulex cheopis*, Rothschild, in England. *Entomologist's Monthly Magazine* 41: 139.

Gomez MS, Gallego J, Bernat G (1987) Observaciones sobre la fauna de anopluros parásitos de micromamíferos de la región catalana (España). *Revista iberica de parasitología* 47: 81–87

Hellenthal RA, Price RD, Palma RL (2004) *Chewing Lice of Belgium*. http://bch-cbd.naturalsciences.be/belgium/biodiversity/faunaflorahabitats/belchewinglice.pdf.

Himonas CA, Liakos VD (1989) Field trial of cypermethrin against lice infestation in goats. *The Veterinary Record* 125: 420–421.

Hopkins GHE, Rothschild M (1953) *An illustrated catalogue of the Rothschild collection of fleas (Siphonaptera) in the British Museum (Natural History). Vol.I: Tungidae, Pulicidae*. London: The Trustees of the British Museum.

Ilieva M (2009) Checklist of the chewing lice (Insecta: Phthiraptera) from wild birds in Bulgaria. *Zootaxa* 2138: 1–66.

Ilvento A (1913) Hygienische Beobachtungen über Ratten und Pestprophylaxie im Hafen von Palermo (1906–1910). *Archiven für Schiffs-und Tropen- Hygiene* 17: 404–413.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Délemont: CABI Bioscience Switzerland, 131–212.

Keymer IF (1983) Diseases of squirrels in Britain. *Mammal Review* 13: 155–158.

Kopocinski B, Lonc E, Modrzejewska M (1998) Fitting a bivariate negative binomial model to the distribution of bird lice (Phthiraptera, Mallophaga) parasitizing the pheasant (*Phasianus colchicus* L.). *Acta Parasitologica* 43: 81–85.

Krause AH (1911) Beitrage zur kenntnis der insektenfauna Sardiniens. Entomologische *Rundschau* 28: 1–149.

Laurie EMO (1946) The coypu (*Myocastor coypus*) in Great Britain. *Journal of Animal Ecology* 15: 22–34.

Lavier G (1921) *Les parasites des Invertébrés hématophages, parasites qui leur sont propres, parasites qu'ils transmettent aux Vertébrés*. Paris: Vigot. 218 pp.

Mahnert V (1974) Quelques parasites (Anoploures, Siphonaptères) de micromammifères nouveaux pour la région de Genève. *Bulletin de la Société Entomologique Suisse* 47: 327–330

Mey E (1988) Uebersicht über die Säugtiere-Mallophagen Europas. *Angewandte Parasitologie* 29: 113–126.

Mey E (2005) *Fauna Europaea. Phthiraptera.* Available at [http//www.faunaeur.org] Retrieved 15.02. 2010.

Mifsud D, Borg JJ, Sultana J (2008) First record of *Xenopsylla gratiosa* Jordan & Rotschild, 1923 from the Maltese islands (Siphonaptera: Pulicidae). *Bulletin of the Entomological Society of Malta* 1: 43–45.

Mouchet J, Morel P (1957) Contribution a I'étude des Mallophages de France. *Bulletin de la Société Entomologique de France* 62: 153–159.

Najera L (1942) La distribution geografica de las especies de pulgas de interés epidemiologico. *Boletín de la real Sociedad Española de Historia Natural*. 40: 497–502.

Newson RM, Holmes RG (1968) Some Ectoparasites of the Coypu (Myocastor coypus) in Eastern England. *Journal of Animal Ecology* 37: 471–481.

Nitzsch CL (1818) Die Familien u. Gattungen der Thierinsecten (Insecta epizoica) aIs ein Prodromus der Naturgeschichte derselben. *Magazin für die Entomologie, Germar, Zincken* 3: 261–316.

O'Connor JP, Sleeman DP, Butler FT (2005) A review of the Irish Anoploura (Insecta: Phthiraptera). *Irish Naturalist Journal* 28: 62–67.

Paradiznik V (1989) *Gliricola porcelli* (L. 1758), Mallophaga, Amblycera, on the guineapig, *Cavia cobaya. Zbornik Biotehniske Fakultete Univerze Edvarda Kardelja v Ljubljani, Veterinarstvo* 26: 211–213.

Pavlovic I, Nesic D (1991) Parasite fauna in intensively farmed poultry in Serbia in 1989. *Veterinarski Glasnik* 45: 390–394.

Peus F (1963) Flöhe aus dem Mittelmeergebiet (Siphonaptera). IV. Sardinien, Korsika und benachbarte kleine Inseln. *Beiträge zur Entomologie* 13: 429–438

Piaget E (1880) *Les Pédiculines. Essai monographique*. Leyden: E. J. Brill. 714 pp.

Prelezov PN, Koinarski VTs (2006) Species variety and population structure of Mallophaga (Insecta: Phthiraptera) on chickens in the region of Stara Zagora. *Bulgarian Journal of Veterinary Medecine* 9: 193–200.

Price RD, Hellenthal RA, Palma RL, Johnson KP, Clayton DH (2003) *The chewing lice: world checklist and biological overview.* Illinois Natural History Survey Special Publication 24. 501 pp.

Rothschild NC (1899), Irish fleas. Irish Naturalist 8(12): 266.

Rothschild NC (1903), A new British flea: *Ceratophyllus londiniensis*. *Entomologist's Record* 15: 64–65.

Schrank F von P (1781) *Enumeratio Insectorum Austriae Indigenorum*. Vienna, Austria: August Vindelicor, Klett. 548 pp.

Šefrová H, Laštùvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Séguy E (1924) *Les Insectes parasites de l'homme et des animaux domestiques*. Paris: Paul Lechevalier. 422 pp.

Séguy E (1944) *Insectes Ectoparasites (Mallophages, Anoploures, Siphonaptéres), 43. Faune de France*. Paris: Paul Lechevalier et Fils. 684 pp.

Silfverbeg H (1984) Mallophaga. In: Huldén L (Ed) A Check list of the Finnish Insects Small Orders. *Notulae Entomologicae* 64: 1–29. Available on http://www.funet.fi/pub/sci/bio/life/warp/insects-fi-Finnish-list.html.

Smit FGAM (1957) *Siphonaptera. Handbooks for the Identification of British Insects Vol. 1 Part 16*. London: Royal Entomological Society. 94 pp.

Smit FGAM (1966) *Insecta Helvetica. I Siphonaptera*. Lausanne: Société Entomologique de Suisse. 106 pp

Smith VS (2003) Lousy Phylogenies: Phthiraptera Systematics and the Antiquity of Lice. *Entomologische Abhandlungen* 61: 150–151.

Soledad Gomez Lopez M (2005) *Fauna Europaea. Siphonaptera.* http//www.faunaeur.org. [accessed 22.2. 2010].

Stefański W (1970) *Parazytologia weterynaryjna tom II*. Warszawa: Państwowe Wydawnictwo Rolnicze i Leśne. 77 pp.

Stojcevic D, Mihaljevic Z, Marinculic A (2004) Parasitological survey of rats in rural regions of Croatia. *Veterinární medicína Czech* 49: 70–74.

Sychra O, Harmat P, Literák I (2008) Chewing lice (Phthiraptera) on chickens (*Gallus gallus*) from small backyard flocks in the eastern part of the Czech Republic. *Veterinary parasitology* 152: 344–348.

Tanon L (1923) Le laboratoire de prophylaxie de la Peste à la Préfecture de Police. *Annales d'hygiène publique, industrielle et sociale*: 606–625.

Thompson GB (1939) A check-list and host-list of the ectoparasites recorded from British birds and mammals. Part I. Mammals (excluding Bats). *Transactions of the Society for British Entomology* 6: 1–22

Tiraboschi C (1904) Les rats, les souris et leurs parasites cutanés dans leur rapport avec la propagation de la pest bubonique. *Archives de Parasitologie* 8: 161–349.

Touleshkov K (1954) Les poux (Anoplura) ectoparasites sur les animaux domestiques et l'homme. *Izvestiya na Zoologicheskiya Institut* 3: 125–160.

Touleshkov K (1955a) Mallophaga - ectoparasites on domestic animals in Bulgaria. *Comptes-Rendus de l'Academie Bulgare des Sciences* 8: 77–80.

Touleshkov K (1955b) Les *Trichodectes* (Trichodectoidea, Mallophaga) ectoparasites sur les mammifères de Bulgarie. *Izvestiya na Zoologicheskiya Institut* 4: 423–434.

Touleshkov K (1957) [Mallophaga of birds of prey in Bulgaria] (in Bulgarian). *Izvestiya na Zoologicheskiya Institut* 6: 275–303.

Touleshkov K (1974) Mallophagen auf den Vögeln des Balkangebirges. *Izvestiya na Zoologicheskiya Instituts Muzey* 41: 207–228.

Wegner Z (1966) Wszy Anoplura. *Catalogus faunae Poloniae* 19 (2): 1–32.

Wegner Z, Eichler WD (1968) Fauna of Lice found on Hares in the Poznań province (Poland). *Biuletyn Instytutu Medycyny Morskiej w Gdansku* 19: 217–224.

Yvinec JH, Ponel P, Beaucournu JC (2000) Premiers apports archéoentomologiques de l'étude des puces (Insecta-Siphonaptera), aspects historiques et anthropologiques (Siphonaptera). *Bulletin de la Société entomologique de France* 105: 419–425.

Zapatero Ramos LM, Rodríguez Rodríguez JA, González-Santiago PI (1982). Ectoparásitos de Múridos Ibéricos e Insulares. *Revista Ibérica de Parasitologia* vol. extra: 113–124.

Table 13.4.1. List and characteristics of the Phthiraptera and Siphonatera species alien *to* Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 27/03/2010;

Order *Suborder* Family	Species	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Phthiraptera *Anoplura*									
Enderleinellidae	*Enderleinellus longiceps* Kellogg & Ferris, 1915	A	parasitic/ predator	North America	1979	GB	G, I2	*Sciurus carolinensis*	Britt and Molyneux (1979), O'Connor et al (2005)
Enderleinellidae	*Enderleinellus tamiasis* Fahrenholz, 1916	A	parasitic/ predator	Asia (Korea)	1916	DE, FR	G, I2	*Tamias sibiricus*	Beaucournu et al (2008), Durden and Musser (1994)
Hoplopleuridae	*Hoplopleura sciuricola* Ferris, 1921	A	parasitic/ predator	North America	1976	GB, IE	G, I2	*Sciurus carolinensis*	Britt and Molyneux (1979), O'Connor et al (2005)
Linognathidae	*Linognathus stenopsis* (Burmeister, 1838)	C	parasitic/ predator	Crypto-genic	1838	BG, CH, CZ, DE, FR, GR, IT	J	Goat (*Capra*)	Fauna Italia (2003), Himonas and Liakos (1989), Piaget (1880), Šefrová and Laštùvka (2005), Séguy (1924, 1944) Touleshkov(1954)
Linognathidae	*Solenopotes muntiacus* Thompson, 1938	A	parasitic/ predator	Asia	1983	GB	G	Muntjac deer (*Muntiacus reevesi*)	Dansie et al (1983), Durden and Musser (1994)
Polyplacidae	*Haemodipsus lyriocephalus* (Burmeister, 1839)	C	parasitic/ predator	Crypto-genic	1839	BG, CH, CZ, DE, FI, FR, GB, IT, NL, PL	E	Hares (*Oryctolagus*)	Broekhuizen (1971), Fauna Italia (2003), Geiter et al (2002), Kenis (2005), Piaget (1880), Séguy (1924, 1944), Thompson (1939), Touleshkov(1954), Wegner (1966), Wegner and Eichler (1968), Büttiker and Mahnert (1978), Šefrová and Laštùvka (2005), Silfverbeg (1984)

Order ***Suborder*** **Family**	**Species**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Polyplacidae	*Polyplax spinulosa* (Burmeister, 1839)	A	parasitic/ predator	Asia	1839	BG, CH, CZ, DE, ES, FI, FR, HR, PL	J	Rats(*Rattus* spp.)	Geiter et al (2002), Gomez et al (1987), Kenis (2005), Šefrová and Laštùvka (2005), Séguy (1944), Silfverbeg (1984), Stojcevic et al (2004), Touleshkov (1954)
Phthiraptera ***Amblycera***									
Gliricolidae	*Gliricola porcelli* (Schrank 1781)	A	parasitic/ predator	C & S America	1781	AT, BG, CH?, DE, ES, FI, FR, HU, IT, PL, RO, SI	J	Guinea pigs (*Cavia porcellus*)	Bordeaul (2008), Fauna Italia (2003), Geiter et al (2002), Kenis (2005), Mouchet and Morel (1957), Paradiznik (1989), Piaget (1880), Schrank (1781), Séguy (1924, 1944) Touleshkov (1955a)
Gyropidae	*Gyropus ovalis* Burmeister, 1838	A	parasitic/ predator	C & S America	1838	AT, BG, CH?, DE, ES, FI, FR, HR, HU, IT, PL	J	Guinea pigs (*Cavia porcellus*)	Bordeau (2008), Fauna Italia (2003), Geiter et al (2002), Kenis (2005), Mouchet and Morel (1957), Piaget (1880), Séguy (1924, 1944), Stojcevic et al (2004),Touleshkov (1955a)
Gliricolidae	*Pitrufquenia coypus* Marelli 1932	A	parasitic/ predator	C & S America	1932	AT, BE, CH? , DE, GB	C2	Coypu (*Myocastor coypus*)	Hellenthal et al (2004), Kenis (2005), Laurie (1946), Newson and Holmes (1968)
Menoponidae	*Eomenacanthus stramineus* (Nitzsch 1818)	C	parasitic/ predator	Crypto-genic	1818	BG, DE, ES, FI, FR, IT, PL, RS, UA	E, J	Pheasant (*Phasianus*), Domestic fowl (*Gallus gallus domesticus*), Turkey (*Meleagris*)	Geiter et al (2002), Ilieva (2009), Mouchet and Morel (1957), Nitzsch (1818), Pavlovic and Nesic (1991), Prelezov and Koinarski (2006), Séguy (1924, 1944),

Order *Suborder* Family	Species	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Menoponidae	*Hohorstiella gigantea lata* (Piaget 1880)	C	parasitic/ predator	Crypto-genic	1880	BE, BG, DE, ES, FI, FR, HU, PL, RO	J	*Columba*	Hellenthal et al (2004), Ilieva (2009), Piaget (1880), Séguy (1924, 1944), Touleshkov (1974)
Menoponidae	*Menopon gallinae* (L. 1758)	C	parasitic/ predator	Crypto-genic	1781	BE, BG, DE, ES, FI, FR, GB, HU, IT, PL, RO, RS, UA	J	Domestic fowl (*Gallus gallus domesticus*), Turkey (*Meleagris*)	Denny (1842), Geiter et al (2002), Hellenthal et al (2004), Ilieva (2009), Mouchet and Morel (1957), Pavlovic and Nesic (1991), Pigate (1880), Prelezov and Koinarski (2006), Schrank (1781), Séguy (1924, 1944), Silfverbeg (1984), Touleshkov (1955a)
Menoponidae	*Myrsidea quadrifasciata* (Piaget, 1880)	A	parasitic/ predator	Asia	1880	BE, CZ, DE, FR, HU, IT	J, J1	House sparrow (*Passer domesticus*)	Hellenthal et al (2004), Piaget (1880), Šefrová and Laštùvka (2005), Séguy (1924, 1944),
Menoponidae	*Neocolpocephalum turbinatum* (Denny 1842)	C	parasitic/ predator	Crypto-genic	1842	BG, DE, ES, FR, GB, HU, IT, IT-SAR, PL, RO	G, J	Falcons (*Falco*), *Columba*	Denny (1842), Geiter et al (2002), Ilieva (2009), Piaget (1880), Séguy (1944), Touleshkov (1957)
Menoponidae	*Uchida phasiani* (Modrzejewska & Zlotorzycka, 1977)	A	parasitic/ predator	Asia	1998	CZ, DE, PL	E, J	Pheasant (*Phasianus*)	Šefrová and Laštùvka (2005)
Trimeno-ponidae	*Trimenopon hispidum* Burmeister, 1838	A	parasitic/ predator	C & S America	1966	AT, CH?, DE, FR, FI, HU, PL	J	Guinea pigs (*Cavia porcellus*)	Geiter et al (2002), Kenis (2005), Mouchet and Morel (1957)
Phthiraptera ***Ischnocera***									
Bovicoliidae	*Bovicola* (*Bovicola*) *ovis* (Schrank, 1781)	C	parasitic/ predator	Crypto-genic	1916	BE, BG, CZ, ES, FI, FR, GB, HU, IT, LT, NL, PL, RO	J	Sheep (*Ovis*)	Cummings (1916), Hellenthal et al (2004), Šefrová and Laštùvka (2005), Séguy (1944), Silfverbeg (1984), Touleshkov (1955b)

Order *Suborder* Family	**Species**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Goniodidae	*Chelopistes meleagridis* (Linnaeus, 1758)	A	parasitic/ predator	North America	1877	CZ, DE, ES, FI, FR, HU, IT, NL, PL, PT, RO	J1, G	Wild and domesticated Turkey (*Meleagris*)	Geiter et al (2002), Mouchet and Morel (1957), Piaget (1880), Šefrová and Laštùvka (2005), Séguy (1924, 1944),
Goniodidae	*Goniocotes chrysocephalus* Giebel 1874	C	parasitic/ predator	Crypto-genic	1874	BE, DE, FR, HU, IT, NL, PL, RO, ES	E, J	Pheasant (*Phasianus* spp.)	Fauna Italia (2003), Geiter et al (2002), Hellenthal et al (2004), Piaget (1880), Séguy (1924, 1944),
Goniodidae	*Goniocotes gallinae* (De Geer 1778)	C	parasitic/ predator	Crypto-genic	1880	BE, BG, DE, ES, FI, FR, HU, IT, PL, RS, UA	J	Domestic fowl (*Gallus gallus domesticus*)	Geiter et al (2002), Hellenthal et al (2004), Mouchet and Morel (1957), Pavlovic and Nesic (1991), Piaget (1880), Prelezov and Koinarski (2006), Séguy (1944), Touleshkov (1955a)
Goniodidae	*Goniodes pavonis* (Linnaeus, 1758)	C	parasitic/ predator	Crypto-genic	1892	BG, DE, FI, FR, HU, IT, PL, RO	J	Indian Peafowl (*Pavo cristatus*)	Geiter et al (2002), Fauna Italia (2003), Séguy (1924, 1944), Touleshkov (1955a)
Goniodidae	*Goniocotes rectangulatus* Nitzsch, 1818	C	parasitic/ predator	Crypto-genic	1818	DE, HU, RO	J	Helmeted Guinea Fowl (*Numida meleagris*), Indian Peafowl (*Pavo cristatus*)	Geiter et al (2002), Nitzsch (1818), Piaget (1880)
Goniodidae	*Stenocrotaphus gigas* (Taschenberg 1879)	A	parasitic/ predator	Tropical, sub-tropical	1924	BE, BG, DE, ES, FR, GB, IT, PL	J1	Domestic fowl (*Gallus gallus domesticus*), Turkey (*Meleagris*)	Geiter et al (2002), Hellenthal et al (2004), Ilieva (2009), Séguy (1924), Touleshkov (1955a)

Order ***Suborder*** **Family**	**Species**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Goniodidae	*Zlotorzyckella colchici* (Denny, 1842)	A	parasitic/ predator	Asia	1977	BE, CZ, DE, ES, IT, PL, RO	G, I2	Pheasant (*Phasianus*)	Dlabola (1977), Hellenthal et al (2004)
Philopteridae	*Cuclotogaster heterographa* (Nitzsch in Giebel 1866)	C	parasitic/ predator	Crypto-genic	1876	BE, BG, DE, ES, FI, FR, HU, IT, NL, PL, RO,UA	J	Domestic fowl (*Gallus gallus domesticus*)	Fauna Italia (2003), Geiter et al (2002), Hellenthal et al (2004), Mouchet and Morel (1957), Piaget (1880), Séguy (1924, 1944), Touleshkov (1955a)
Philopteridae	*Lagopoecus colchicus* Emerson, 1949	A	parasitic/ predator	Asia	1989	BE, CZ, DE, PL	G, I2	Pheasant (*Phasianus colchicus*)	Geiter et al (2002), Hellenthal et al (2004), Šefrová and Laštùvka (2005)
Philopteridae	*Lipeurus maculosus* Clay, 1938	A	parasitic/ predator	Asia	1938	BE, CZ, DE, GB, HU, IT, PL, RO	G, I2	Pheasant (*Phasianus colchicus*), Partridge (*Perdrix perdrix*)	Clay (1938), Dlabola (1977), Fauna Italia (2003), Geiter et al (2002), Hellenthal et al (2004)
Philopteridae	*Reticulipeurus* (=*Oxylipeurus*) *polytrapezius* (Burmeister 1838)	C	parasitic/ predator	Crypto-genic	1880	BG, DE, FR, IT	J	Turkey (*Meleagris*)	Fauna Italia (2003) Geiter et al (2002), Mouchet and Morel (1957), Piaget (1880), Séguy (1944)
Trichodectidae	*Trichodectes* (*Stachiella*) *octomaculatus* Paine 1912	A	parasitic/ predator	North America	Unknown	AT, BE, CH?, DE	F9	Raccoon (*Procyon lotor*)	Geiter et al (2002), Hellenthal et al (2004), Kenis (2005)
Trichodectidae	*Trichodectes* (*Trichodectes*) *canis* (De Geer 1778)	C	parasitic/ predator	Crypto-genic	<1880	BE, BG, DE, ES, FI, FR, IT, PL	J	Dogs (*Canis domesticus*)	Fauna Italia (2003), Hellenthal et al (2004), Mouchet and Morel (1957), Piaget (1880), Séguy (1924, 1944), Touleshkov (1955b)

Order *Suborder* Family	**Species**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Siphonaptera									
Ceratophyllidae	*Callopsylla* (*Geminopsylla*) *gemina* (Ioff, 1946)	A	parasitic/ predator	Asia	1985	CH	J1	Man (*Colomba livia* in the native range)	Beaucornu and Aeschlimann (1985)
Ceratophyllidae	*Leptopsylla* (*Leptopsylla*) *segnis* (Schönherr, 1811)	C	parasitic/ predator	Crypto-genic	1811	AL, AD, AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FÖ, FR, FR-COR, GR, GR-CRE, GR_NEG, GR-SEG, GB, HR, HU, IE, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, MD, MK, MT, NL, PL, PT, PT-AZO, PT-MAD, RO, SK	J1, J2	*Mus domesticus*, *Rattus rattus* and other Muridae (fur fleas)	Beaucornu and Launay (1990), Dale (1878), Rotschild (1899), Soledad Gomez Lopez (2009), Stojcevic et al (2004)
Ceratophyllidae	*Nosopsyllus* (*Nosopsyllus*) *fasciatus* (Bosc dAntic, 1800)	A	parasitic/ predator	Asia-Tempe-rate	1900	AT, BE, CH, CZ, DE, DK, ES, ES-BAL, FÖ, FR, FR-COR, GB, GR, HU, IE, IT, IT-SAR, IT-SIC, LT, LU, ME, MT, NL, PL, PT, PT-AZO, PT-MAD, RO, RS, SK	E,J	*Rattus* spp., *Apodemus* spp., *Mus* spp. and other Muridae	Beaucornu (1972, 1976, 1978), Beaucornu and Alcover (1984), Beaucornu and Launay (1990), Beaucornu and Pascal (1998), Galli-Valerio (1900), Krause (1911), Mifsud et al (2008), Peus (1963), Smit (1957, 1966), Soledad Gomez Lopez (2009)

Order *Suborder* Family	Species	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Ceratophyllidae	*Orchopeas howardi* Baker 1895	A	parasitic/ predator	North America	1800	GB, IE	G, X11	*Sciurus carolinensis* (grey squirrel), *Clethrio-nomys glareolus, Glis glis, Dama dama, Vulpes vulpes, Oryctolagus cuniculus*	Anonymous (1994),Donisthorpe (1925)
Pulicidae	*Euhoplopsyllus glacialis affinis* (Baker, 1904)	A	parasitic/ predator	North America	1977	FR, IT	E, F, G	cottontail, rabbit *Sylvilagus floridanus, Oryctolagus cuniculus*	Beaucornu and Launay (1977), Beaucornu et al (1981), Fauna Italia (2003)
Pulicidae	*Xenopsylla brasiliensis* (Baker, 1904)	A	parasitic/ predator	Africa	1942	ES-CAN, GB	J1	*Rattus* spp., vector of plague and murine typhus	Beaucornu and Launay (1990), Hopkins and Rotschild (1953), Najera (1942), Smit (1957),
Pulicidae	*Xenopsylla cheopis cheopis* (Rothschild, 1903)	A	parasitic/ predator	Africa(Nile region)	1904	DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, IE, IT-SIC, IT, MT, PL, PT-AZO, PT-MAD, PT, RU	J1	*Rattus norvegicus, R. rattus*, humans, *Mus musculus*; vector of plague	Bernard et al (1947), Beaucornu and Launay (1990), Cartana Castella and Gil-Collado (1934), Giles (1905), Ilvento (1913), Lavier (1921), Najera (1942), Séguy (1924), Tanon (1923), Tiraboschi (1904), Zapatero-Ramos et al (1982),

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Springtails and Silverfishes (Apterygota) Chapter 13.5

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Abstract

The alien fauna of Apterygota is still limited in Europe. Springtails (Collembolla) alien *to* Europe include only three species to which add a cryptogenic one. Two nowadays cosmopolitan species of silverfishes may originate from Central America. The reasons of this limited colonisation of Europe are briefly discussed.

Keywords

Apterygota, Collembola, springtails, Zygentoma, silverfishes

13.5.1. Diplura alien to Europe

No introductions of alien species into Europe are known.

13.5.2. Collembola (Springtails) alien *to* Europe

Worldwide ca. 6500 collembolan species are listed, belonging to 18 families (Hopkin 1997). For Europe, there are estimated to be ca. 1500 species, belonging to 16 families (taxonomic work is still progressing).

Collembola are the most abundant terrestrial arthropods, colonising all soil habitats that provide enough humidity and food, such as organic matter or microorganisms. Example habitats include root rosettes of high alpine plants, plant debris on the shore, natural soils, as well as microhabitats such as flower pots. Most species are soil or litter dwellers, whilst only few species live on the surface or in the vegetation (mainly Entomobryidae and Symphypleona). In mature soil, abundances may attain values of 50–100‘000 individuals/m^2. Local gradations in abundance are a well known phenomenon in many Collembola.

As detritivores, Collembola are not generally considered as pest species. Exceptions are two species of Symphypleona living above ground in the vegetation layer: the European *Sminthurus viridis* which became a severe pest in Australia on alfalfa, clover etc, and the ubiquitous *Bourletiella hortensis* is known to feed on vegetable seedlings when natural food (weed seedlings) is absent. The ubiquitous onychiurid *Protaphorura armata* also switches food source in the absence of weeds, but only as a secondary pest when feeding on wounds infected by microorganisms. In Europe, no Collembola are declared as agronomic pests (e.g. in CABI Crop Protection Compendium) (CABI 2009).

A 100 or more Collembola species may occur in the same soil habitat, and through occupying all available niches are believed to preclude establishment of alien species. To date, alien Collembola have only been observed to become invasive and replace indigenous species in isolated microhabitats and in extreme climates such as two species on sub-Antarctic islands (Convey et al. 1999, Greenslade 2002).

Identifying alien Collembola is difficult due to the limited number of specialists investigating soil fauna. No intentional introductions to Europe have occurred. Unintentional transport within soil of ornamental plants, with vegetables, dirty equipment and vehicles easily moves Collembola over large distances. Short life cycles and parthenogenetic development of a number of species may also increase the chances to colonise new sites. Therefore the distribution ranges of alien species within Europe may increase steadily.

Only three records of alien Collembola introduced to Europe have been published. These concern two species in the family Isotomidae, *Proisotoma filifera,* originating from Central America but found in Dutch greenhouses (Ellis 1970), and *Desoria trispinata*, that originates from North America but has appeared in anthropogenic habitats, mainly towns (Christian 1987, Christian and Kindl-Stomatopolos 1999, Kindl- Stomatopoulos). A third species in the family Onychiuridae, *Onychiurus folsomi*, originating from Australia, is restricted to earthworm cultures in Spain (Arbea and Jordana 1988). In addition, we considered a cryptogenic species, *Sminthurinus trinotatus* (Katiannidae), which presents a very disjunct known distribution (southern Europe, eastern Asia).

13.5.3. Zygentoma (Silverfishes) alien *to* Europe

Zygentoma or silverfishes comprise five families (in Europe Lepismatidae only) with 12 genera (three in Europe) and ca. 370 species (ten in Europe). The two (today) cosmopolitan species *Ctenolepisma longicaudata* and *Thermobia domestica* (both Lepismatidae), may originate from central parts of America. Once moved from western Mediterranean regions to central and northern Europe, they mainly colonise anthropogenic habitats, where they may become pests by destroying paper or stored products.

References

Arbea JL, Jordana R (1988) Nota sobre la presencia masiva de *Onychiurus folsomi* Schaeffer (Collembola, Onychiuridae) en lechos de *Eisenia andrei* (Oligochaeta, Lumbricidae). *Boletin de Sanidad Vegetal Plagas* 14: 535–540.

CABI Crop Protection Compendium. http://www.cabicompendium.org/cpc.

Christian E (1987) *Collembola (Springschwänze). Catalogus Faunae Austriae XIIa*, Wien: Österreichische Akademie der Wissenschaften. 80 pp.

Christian E, Kindl-Stamatopolos L (1999) Arthropods on plastered riverbanks in the builtup area of Vienna. In: Tajovský K, Pižl V (Eds) *Soil Zoology in Central Europe. Proceedings of the 5th Central European Workshop on Soil Zoology, April 1999.* České Budějovice: Institute of Soil Biology, 27–30.

Convey P, Greenslade P, Arnold RJ, Block W (1999) Collembola of subantarctic South Georgia. *Polar Biology* 22: 1–6.

Ellis WN (1970) *Proisotoma filifera* Denis in Holland, with a note on its classification (Collembola, Isotomidae). *Entomologische Berichten* 30: 18–24.

Essl F, Rabitsch W (2002). *Neobiota in Österreich*. Wien: Umweltbundesamt. 432 pp.

8-Greenslade P (2002) Assessing the risk of exotic Collembola invading subantarctic is lands: priorising quarantine management. *Pedobiologia* 46: 338–344.

Hopkin SP (1997). *Biology of the springtails (Insecta:* Collembola). Oxford: Oxford University Press. 330 pp.

Hopkin SP. *The Natural World in Close Up*. available at [www.stevehopkin.co.uk].

Kindl-Stamotopolos L (2001) Arthropoden des Wienflussufers im dicht bebauten Stadtgebiet Wiens. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Österreich* 138: 1–15.

Table 13.5.1. List and characteristics of the Collembola and Zygentoma species alien *to* Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 11/01/2010;

Order-Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**References**
Collembola- Onychiuridae							
Onychiurus folsomi (Schäffer, 1900)	A	detritivorous	Australia	1988 ?, ES	ES, GB	I (Vermiculture), J100	Arbea and Jordana (1988), Hopkin (2009)
Collembola- Isotomidae							
Proisotoma filifera (Denis, 1931)	A	detritivorous	Central America	1968, NL	NL	J100	Ellis (1970)
Desoria trispinata (MacGillivray, 1896)	A	detritivorous	North America	ca 1900, AT	AT, DE, IT, NO, PT, RU	J	Christian (1987), Christian and Kindl-Stomatopolos (1999), Kindl-Stamotopolos (2001)
Collembola- Katiannidae							
Sminthurinus trinotatus (Axelson, 1905)	C	detritivorous	South Europe, East Asia?	1925, GB	AT, DE, FR, GB, IT	I2, J100	Essl and Rabitsch (2002), Hopkin (2009)
Zygentoma- Lepismatidae							
Ctenolepisma longicaudata (Escherich, 1905)	C	detritivorous	Central America?	Unknown	CY, FR, IT, MT, PT	J1 (stored products)	Essl and Rabitsch (2002)
Thermobia domestica (Packard, 1873)	C	detritivorous	Central America?	Unknown	CY, DE, DK, FR, GB, IT, PT	J1 (stored products)	Essl and Rabitsch (2002)

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Introductory notes to factsheets Chapter 14

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Among the 1590 terrestrial arthropod species alien *to* Europe identified in this book, 78 were selected to produce specific factsheets in order to provide more information on their biology, distribution and impact. We included two more species which are alien *in* Europe, the horse-chestnut leaf miner (*Cameraria ohridella*) and the African cotton leafworm (*Spodoptera littoralis*) because of their importance.

These 80 species are perhaps not the most important alien invaders, but they are rather representatives of the main taxonomic groups of alien terrestrial arthropods. They were selected so as to represent different pathways of introduction and diverse impacts on ecosystems, economic activities and human and animal health. These species include two myriapods, one spider, one mite, 18 coleopterans, seven dipterans, 23 hemipterans, 10 hymenopterans, one termite, 14 lepidopterans, and three thrips. Each factsheet includes information on the following aspects:

Description and biological cycle: A brief description of adults and immature stages is given, whenever possible illustrated by a photograph, to help the reader identify the species. Further information details the general characteristics of the biological cycle in the invaded area, especially the species' potential to reproduce and the hosts it has colonized.

Native habitat: The factsheet includes the habitat type where the species is found in its native range. In order to make habitat types comparable among taxa, we adopted the classification of the European Nature Information System (EUNIS) database (http://eunis.eea.europa.eu). The habitat type codes are detailed in Appendix II. When information was available, we included specific habitat requirements which may help understand the potential of the species to establish and spread in Europe.

Habitat occupied in invaded range: The different habitats colonized by the alien species are described as for native habitats.

Native range: The native distribution of the species is described. For some species, there is very precise information available, but for others, only brief details of a region or even continent can be given.

Introduced range: The date of the first record in Europe and the location of this record is given, as well as details of the process of dispersion in the continent when available. A distribution map is supplied for all species. For most of them, presence/absence data have been obtained only at country level, but for a few species, more detailed maps are given to show the distribution at regional scale. However, the missing occurrence of species from some countries does not always mean that these countries are not colonized, but may rather result from a lack of data for the country concerned. The map also indicates eradication records where relevant.

Pathways: We included information on the routes of introduction to Europe, and the potential of the species to disperse within the continent once it has established.

Impact and management: This section details the importance of the species' impacts in the colonized habitats. Both ecological and economical impacts are detailed when known. Practical advice where known is given regarding mechanical, chemical and biological control methods.

Selected references: Three of the most relevant references to the history of the species' introduction and spread in Europe are given.

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14.1 – *Lamyctes emarginatus* (Newport, 1844) (Chilopoda, Henicopidae)

Marzio Zapparoli

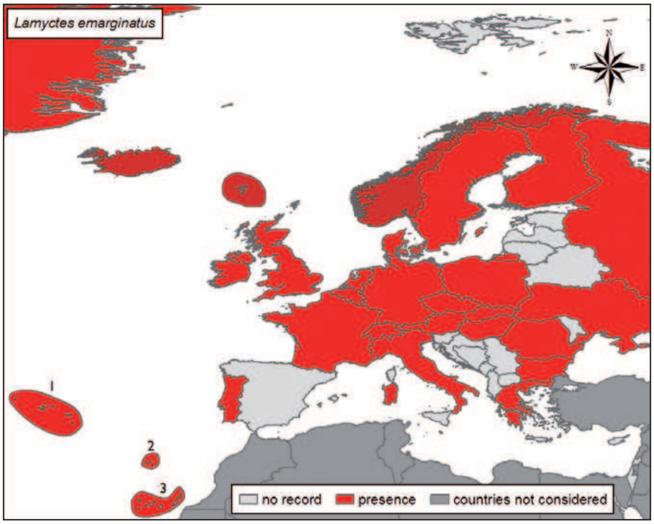
Description and biological cycle: Body length 6.0–10.5 mm, shape slender, feebly fusiform, first tergite distinctly narrower than head and than tergite 3. Chestnut brown to dark brown, with leg tips and antennae yellow (*Photo*). One ocellus only at each side of the head. Antennae one-third to two-fifths of body length, with 25 segments. 15 pairs of legs, slender and without spines. Tibia of 1st-12th segment with a sharp projection on the anterior edge of its distal extremity. Reliable identification possible only after light microscope examination. *L. emarginatus* is a soil dwelling predator of small invertebrates, apparently hygrophilous and generally solitary. It is a pioneer of disturbed habitats (e.g. mine sites). This centipede develops through five anamorphic larval and five post-larval stadia. The species reproduces by *thelytokous parthenogenesis** (producing only females) in most of its range. Bisexual populations are known in the Azores and Canary Islands, as well as in New Zealand, Tasmania and Hawaii.

Native habitat (EUNIS code): Often collected at banks of creeks and rivers, and under stones where there is moisture. Some records from grasslands (E). In its native range *Lamyctes emarginatus* also commonly colonizes disturbed urban and suburban habitats.

Habitat occupied in invaded range (EUNIS code): In Europe recorded in a wide range of habitats, from open or semi-open habitats (E); cultivated lands (I, X6, X7); city parks (X23); gardens (I1, I2); more or less intensively built-up areas of villages and cities (J1, J2, J4); waste dumps (J6); plant nurseries (I1); mine sites (J3); artificial banks of streams and lakes more or less temporary flooded (J5); also in natural or semi-natural habitats such as woodlands (G1, G3); heathlands (F4); riversides (F9) ; bogs (D) and coastal environments (B1) (British Isles, Faroe Isl., Northern Italy). Almost the same range of habitats is known for North America, New Zealand and Tasmania.

Native range: Australasian species (western and southern Australia).

Credit: Massimo Vollaro



Introduced range: Present in almost all European countries and Atlantic islands (*Map*- not recorded elsewhere probably due to lack of research), Southwestern Asia (Georgia, Iran, Turkey), Africa (Morocco, Ethiopia, Kenya, Tanzania, Somalia), North America (Canada, USA), Central America (Cuba, Guadeloupe), South America (Galapagos Islands, Brazil), Hawaii. Probably introduced also in Tasmania (proposed common name: Domestic Woodrunner), New Caledonia, New Zealand, Chatham Islands, Fiji and Kermadec Islands.

Described as a new species by G. Newport from New Zealand in 1844, it has been recorded in Europe for the first time in 1868 in Denmark (Øerne) under the name of *Lamyctes fulvicornis* Meinert, 1868. The species may have been introduced into Europe even earlier, e.g. immediately after the British colonization of the Australian continent (18th century).

Pathways: Mode of introduction and spread of this species is unknown, but probably occurred/occurs by passive transfer in rootballs of transplanted plants in which soil this small species temporarily settles. Parthenogenesis can then help the successful establishment of viable populations. Local-scale dispersal is probably achieved actively.

Impact and management: Unknown, but effects on trophic chains are possible.This species is presently economically unimportant, thus monitoring, chemical or biological control are considered unnecessary.

Selected references

Andersson G (2006) Habitat preferences and seasonal distribution of developmental stadia in *Lamyctes emarginatus* (Newport, 1844) (*L. fulvicornis* Meinert, 1868) and comparisons with some *Lithobius* species (Chilopoda, Lithobiomorpha). Norwegian Journal of Entomology 53: 311–320.

Bocher J, Enghoff H (1984) A centipede in Groenland: *Lamyctes fulvicornis* Meinert, 1868 (Chilopoda, Lithobiomorpha, Henicopidae). Entomologiske Meddelelser 52: 49–50.

Zerm M (1997) Distribution and phenology of *Lamyctes fulvicornis* and other lithobiomorph centipedes in the floodplain of the Lower Oder Valley, Germany (Chilopoda, Henicopidae: Lithobiidae). Entomologica Scandinavica suppl. 51: 125–132.

14.2 – *Oxidus gracilis* (C.L. Koch, 1847) (Diplopoda, Polydesmida, Paradoxosomatidae)

Pavel Stoev and Zoltán Korsós

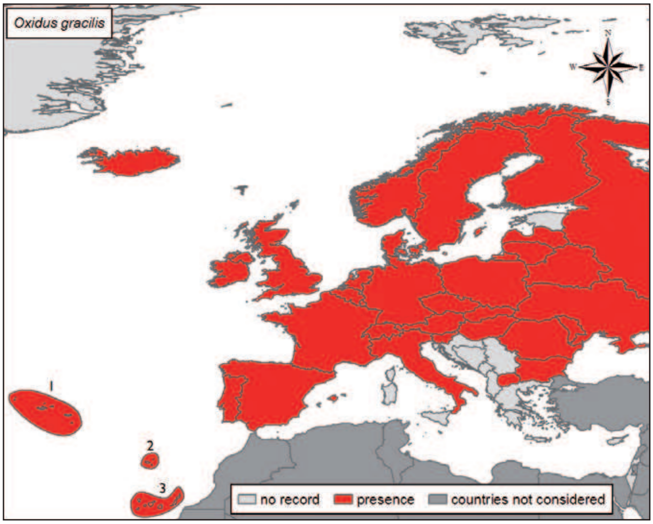
Description and biological cycle: Typical "flat-backed" millipede (Order Polydesmida), body length 16–21 mm (males), 17–23 mm (females). Dorsal surface smooth, chestnut to dark reddish or blackish brown, with lighter, pale yellowish *paranota** ("lateral wings") (*Photo*). Ventral surface and legs, head and antennae also dark brown. Immature stages light amber to cream. Further taxonomic traits and good illustrations of gonopods can be found in Blower (1985).

Native habitat (EUNIS code): From grasslands (E1, E2, E3, E5, E7) to all kinds of woody habitats (G1, G2, G3, G4), miscellaneous inland habitats (e.g. H5), occasionally entering subterranean localities (H1), common in agricultural areas and other places under different degrees of disturbance (I1-I2, J2, J3, J4, J6, X7, X10, X11, X13, X14, X15, X16, X22, X23).

Habitat occupied in invaded range: (EUNIS code): In Europe the'greenhouse millipede' has been recorded most often in hothouses (J100), city parks (X23) and gardens (I1, I2). The only alien millipede to have invaded some natural ecosystems and at least partially acclimatized in Europe. Earliest records in Europe are from the 19th century from Hungary, Austria, Germany, and the Netherlands from greenhouses and cities. Koch's (1847) type locality 'Puloloz' may refer to a locality in former Czechoslovakia or in 'Ostindien'. In North Europe, it was found for the first time in Finland in 1900. In the British Isles, first recorded from Edinburgh (1898) and Kew Gardens.

Native range: East or Southeast Asia. Two other congeners (*O. avia* and *O. riukiaria*) are recently confirmed as validly occurring in the Ryukyu Archipelago, both confined to undisturbed, natural forest habitats. This suggests that the genus might have had a centre of origin in that region.

Credit: Zoltán Korsós



Introduced range: Recorded from 33 European countries, including several Mediterranean islands (*Map*). Also introduced to numerous temperate and tropical countries: USA, Canada, Puerto Rico, Asian part of Russia, Australia, New Zealand, South Africa, Brazil, archipelagos and isolated islands in Indian and Pacific Oceans: Hawaii, New Caledonia, Madagascar, Sandwich Islands, Seychelles, etc.

Pathways: Must have arrived in Europe with goods from East Asia although when is unknown. *Oxidus gracilis* is spreading within Europe mainly with expanding trade and greenhouse tropical plant cultivation. Some populations in Central and South Europe have established themselves naturally, most often close to suburban/urban areas, but also in woodlands in nature reserves and in caves.

Impact and management: A plant-damaging millipede regarded as a pest in several European countries. In some places, its density may exceed 2500 ind./m^2. It is known for attacking vegetable and fruit crops such as sugar beet, potatoes, strawberries, cucumbers, orchard fruits, peanut seedlings, roots of wheat, and flowers in outdoor cultivated areas. No data on impact of *O. gracilis* on native species and its interactions with local invertebrate communities. So far no evidence for wild populations taking over new habitats. The species dies when subjected for two hours to a temperature of -4°C. Thus in Northern Europe, it can survive only in hothouse conditions. Various different chemicals such as Methodyl, Carbaryl and Propuxur proved to be effective for dealing with *O. gracilis*. Another effective method for decreasing the numbers of the species in buildings is the removal of all excess damp organic matter and debris from gardens and associated areas.

Selected references

Blower JG (1985) Millipedes. Keys and notes for the identification of the species. Synopses of the British Fauna 35: 1–242.

Chornyi NG, Golovatch SI (1993) Dvuparnonogie mnogonozhky ravninnych territorij Ukrainy. [Millipedes (Diplopoda) of the plain areas of the Ukraine]. Kiev: Kiev University. 56 pp.

Vicente M, Enghoff H (1999) The millipedes of the Canary Islands. Vieraea 27: 183–204.

14.3 – *Mermessus trilobatus* (Emerton, 1882) (Araneae, Linyphiidae)

Martin H Schmidt-Entling

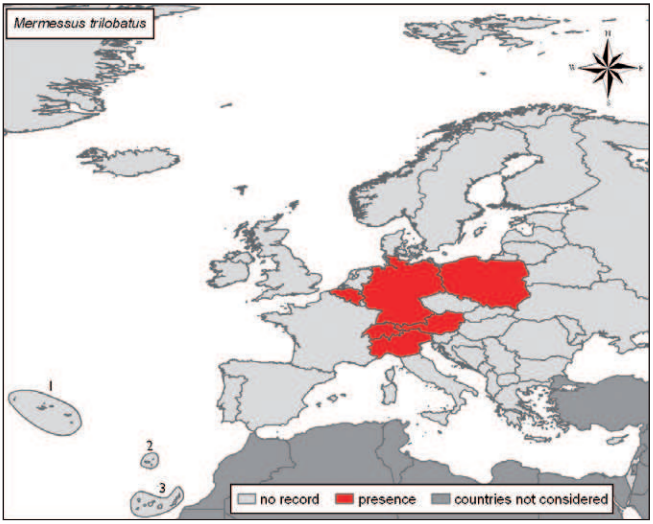
Description and biological cycle: Small, 1.5–2.1 mm long sheetweb spider with orange-brown *prosoma** and legs, gray to black *opisthosoma**and no markings (*Photo*). In contrast to most native European sheetweb spiders, the female *epigyne** is frequently covered with a dark reddish-brown, hemispherical mating plug. Egg sacs light pink with a smooth surface and 3 mm diameter. Individual females produce up to 11 egg sacs. Adults are found year-round, and several generations per year are likely. The species builds small horizontal webs low in the vegetation or at the ground surface. Long distance dispersal is by ballooning (also shown by adults), and possibly by passive transport on road, rail or by aircraft.

Native habitat (EUNIS code): Inhabits various types of E - Grassland and tall forb habitats; I1 - Arable land and market gardens; D – wetlands; B - coastal habitats; G - Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): The species can reach high densities (exceeding 10 adults per m^2) in E- Grassland and tall forb habitat, and in ruderal habitats in both rural and urban areas. It is frequently among the ten most abundant spider species in these habitats in Northern Switzerland. It also occurs on I1 - Arable land and market gardens and in G - Woodland and forest habitats and other wooded land.

Native range: Widely distributed in North America from the Gulf coast (Florida, Mexico) to boreal climate (Northwest Territories, Newfoundland) and from the east to the west coast including the Great Plains.

Credit: Martin H Schmidt Entling



Introduced range: First recorded in 1981 near Karlsruhe, southwestern Germany, *M. trilobatus* spread in all directions with recent records as far as the Netherlands and Italy (near Venice) (*Map*).

Pathways: Presumably transported unintentionally by aircraft, with no evidence for multiple introductions.

Impact and management: Negative impacts on the native fauna are unknown, but are only starting to be explored. Given the wide distribution and high abundance, prey or other predators may be affected through predation or intraguild interference. *M. trilobatus* was the dominant sheetweb spider in nine protected E3.5 - fen meadows in Switzerland, indicating a potential threat to biodiversity. The species can be effectively recorded with vacuum sampling. It is underrepresented in pitfall traps relative to other spiders. Once established, successful control of *M. trilobatus* appears very unlikely. Specialist natural enemies are not known.

Selected references

Dumpert K, Platen R (1985) Zur Biologie eines Buchenwaldbodens, 4. Die Spinnenfauna. Carolinea 42: 75–106.

Eichenberger B, Siegenthaler E, Schmidt-Entling MH (2009) Body size determines the outcome of competition for webs among alien and native sheetweb spiders (Araneae: Linyphiidae). Ecological Entomology 34: 363–368.

Schmidt MH, Rocker S, Hanafi J, Gigon A (2008) Rotational fallows as overwintering habitat for grassland arthropods: the case of spiders in fen meadows. Biodiversity and Conservation 17: 3003–3012.

van Helsdingen PJ, IJland S (2007) *Mermessus* species in the Netherlands (Araneae, Linyphiidae). Nieuwsbrief Spined 23: 27–29.

14.4 – *Varroa destructor* Anderson & Trueman, 2000 - Bee Varroa (Acari, Varroidae)

Maria Navajas and Yves Le Conte

Description and biological cycle: *Varroa destructor* is today's most important honey bee parasite. As an ectoparasite, the mite causes serious damage to honey bee colonies almost worldwide. Varroa feeds on the hemolymph of adult, larval and pupal bees. Adult females are reddish-brown, 1.00–1.77 mm long and 1.50–1.99 mm wide (*Photo- female Varroa on abdomen of Apis mellifera*). Adult males are yellowish with lightly tanned legs and spherical body shape measuring 0.75–0.98 mm long and 0.70–0.88 wide. The male chelicerae are modified for transferring sperm. *Varroa destructor* reproduces by *pseudoarrenotoky**. The female lays eggs in bee brood cells. Developing mites feed on developing honey bee larvae and pupae. Males and females copulate in capped brood cells. The male dies, but fertilized females emerge from the cell along with their bee host and seek a nurse bee on which it feeds for a few days and then repeat the cycle. In temperate climates, *V. destructor* populations complete an average of 10 generations per year.

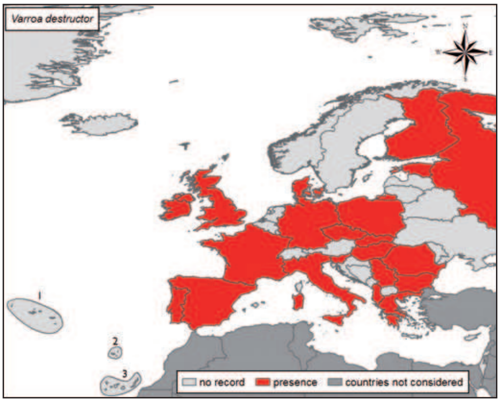
Native habitat (EUNIS code): J1- Hives.

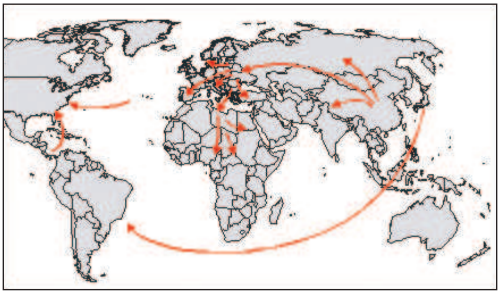
Habitat occupied in invaded range (EUNIS code): J1- Hives.

Native range: South East Asia, where it was originally confined on its original host, the Asian honey bee, *Apis cerana*. Importation of commercial *A. mellifera* colonies into areas with *A. cerana* brought this previously allopatric bee species into contact and allowed *V. destructor* to switch to the new host. While the populations of the parasite reach only a small size within colonies of *A. cerana* and do not damage the colony, infested *A. mellifera* colonies die.

Introduced range: practically worldwide except Australia, the state of Hawaii and some parts of Africa remain free of this pest (*see lower Map for known spread routes of Varroa*). First reported in the Eastern Europe in the 70s, it spread rapidly all over the continent (*see upper-Map*). Two different genotypes (characterized by mitochondrial DNA sequences) have spread as independent clonal populations: the Korean and the Japanese haplotypes, the later having been found, besides Asia, in The Americas only. International travel and commerce has facilitated the varroa dispersal.

Credit: Alain Migeon





Pathways: Once established in a new region, the mite spread using drifting, robbing, and swarming behaviour of the host. Human mediated varroa dispersion also occurs by apicultural practices. The importation of honey bees from infested areas, and the movement of infested colonies for pollination or hives *transhumance** led to the rapid spread of this mite.

Impact and management: Although several chemicals are applied against honey bee larvae and adults, pesticide-resistant varroa populations occur. In addition, there is much concern about chemical residues in hive products. Alternative varroa control methods are attempted, including the use of organic acids, as formic acid, but they are temperature dependent and can be dangerous to humans. Another efficient varroa control is the use of plant volatile essential oil extracts. These different methods used in combination with an integrated pest management (IPM) plan, including bee colony management techniques (e.g. removal of the infested brood) may be helpful. The recent detection of varroa-resistant honeybee stocks is a promising avenue for honeybee breeding.

Selected references

De Rycke PH, Joubert JJ, Hossein Hosseinian S, Jacobs FJ (2002) "The possible role of *Varroa destructor* in the spreading of American foulbrood among apiaries." Experimental and Applied Acarology 27: 313–318.

Le Conte Y, de Vaublanc G, Crauser D, Jeanne F, Rousselle JC, Bécard JM (2007) Honey bee colonies that have survived *Varroa destructor*. Apidologie 38: 566–572.

Martin C, Provost E, Roux M, Bruchoux C, Clément JL, Le Conte Y (2002) Potential mechanism for detection by *Apis mellifera* of the parasitic mite *Varroa destructor* inside sealed brood cells by *Apis mellifera*. Physiological Entomology, 27: 175–188.

14.5 – *Agrilus planipennis* Fairmaire, 1888 - Emerald Ash Borer (Coleoptera, Buprestidae)

Yuri Baranchikov

Description and biological cycle: Adults 7–15 mm long and 3–3.4 mm wide. Body narrow, elongate and metallic coppery-green (*Photo left*). Eyes large, black- or copper-coloured. Emerald Ash Borer has four larval instars. Mature larvae 26–32 mm long , creamy white with head brown (*Photo right*). Pre-pupal body characteristically J-shaped. Pupa *exarate**, initially beige, later darkening. Adults emerge from ash trees through distinct D-shaped exit holes chewed through the bark. Adults found in June-early August, flying near the host trees and feeding on leaves. After several weeks of maturation, feeding and mating, female deposits up to 270 eggs, singly or in small clusters in bark crevices. Larvae form distinct S-shaped galleries, widening as they grow. Larvae mostly found under the bark during summer and some may be present all year around. Full development takes 1–2 years. All European and most American ash species highly susceptible to infestation. Up to three years's attack can kill a middle-sized ash tree. All species of *Fraxinus* can be used as hosts. Reportedly, *Agrilus planipennis* colonize *Ulmus, Juglans* and *Pterocarya* in Asia; in the USA it can lay eggs on *Ulmus americana, Celtis occidentalis, Carya ovata* and *Syringa reticulata*, but larvae die in early instars.

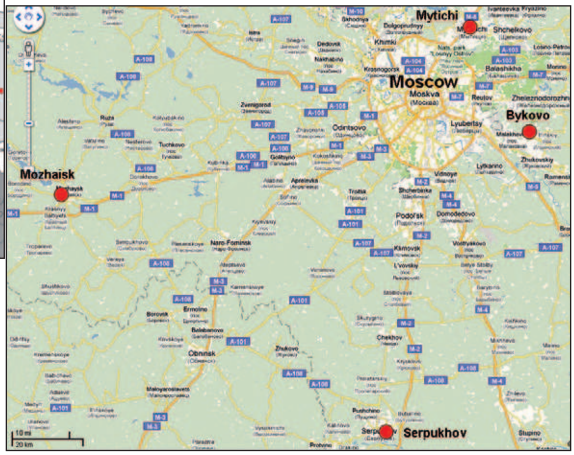
Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland; G4 - Mixed deciduous and coniferous woodland.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I2 - Cultivated areas of gardens and parks; X24 Domestic gardens of city and town centres; X25 Domestic gardens of villages and urban peripheries.

Native range: North Eastern China, Korea Japan, Taiwan, Eastern Mongolia and the Southern part of the Russian Far East.

Introduced range: First discovered in Michigan, USA, in June 2002 and in Ontario, Canada, in August 2002 (Cappaert *et al.,* 2005). *Agrilus planipennis* then established in 11 states in North-Eastern USA and adjacent provinces of Canada, expanding very fast. In the early 2000s, introduced to European Russia (*see upper Map*) where ash trees were killed within

Credit: David Cappaert, Michigan State University, Bugwood.com



a 100 km radius of Moscow; since has spread westwards. In approximately 10 years the beetle spread 95 km to the West, 90 km to the South, 30 km to the East and 20 km to the North. (*see lower Map*- red points detailing the outer spots of infestation in Moscow area in 2009).

Pathways: transportation with wood for industry and firewood. Adults are active flyers.

Impact and management : In < 10 years, this buprestid killed an estimated over 20 million forest and ornamental trees in North America. In Europe, the ecological impact manifests in fast dieback of all ashes in cities and forests, irrespective of their previous condition. Only Asian species of ashes are relatively resistant to the pest, so the beetle poses one of the most important economic threats to trees in Western Europe. In Asia, controlled by a few hymenopteran parasitoid species: eggs are attacked by *Oobius agrili* Zhang and Huang (Encyrtidae); larvae are infested by the gregarious endo-parasitoid *Tetrastichus planipennisi* Yang (Eulophidae) and the gregarious idiobiont ectoparasitoid *Spathius agrili* Yang (Braconidae). Two other braconids (*Spathius depressithorax* Belokobylskiy and *S. generosus* Wilkinson) have been found on larvae in Far Eastern Russia. Woodpeckers are active predators of larvae and pupae. Introduction of some parasitoid species is successfully implemented in the US. Traps with attractants are actively used to monitor spread. A dozen systemic insecticide formulations are used to protect individual ash trees in settlements and historical places.

Selected references

Anulewicz AC, McCullough DG, Cappaert DL, Poland TM (2008) Host range of the emerald ash borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae) in North America: results of multiple-choice field experiment. Environmental Entomology 37: 230–241.

Baranchikov Y, Mozolevskaya E, Yurchenko G, Kenis M (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. Bulletin OEPP/EPPO Bulletin 38: 233–238.

Cappaert D, McCullough DG, Poland TM, Siegert NW (2005) Emerald ash borer in North America; a research and regulatory challenge. American Entomologist 51: 152–165.

14.6 – *Anoplophora chinensis* (Förster, 1848) (=*A. malasiaca* (Thompson, 1865) - Citrus longhorn beetle (Coleoptera, Cerambycidae)

Daniel Sauvard

Description and biological cycle: Large, 21–37 mm long, stout beetle with shiny black elytra marked with 10–12 white round spots (*Photo left*). Antennae long, basally marked with white or light blue bands. The larva is a legless grub creamy white in colour, up to 50 mm long when fully grown (*Photo right*). Polyphagous insect attacking over 100 species of broadleaved trees and shrubs (*Acer, Betula, Carpinus, Citrus, Corylus, Rosa* and deciduous shrubs). Adults can fly up to 1.5 km from their emergence place. Human-mediated long-distance dispersal is possible via infested wood movement or adults hitch-hiking on vehicles. Females lay eggs throughout their lifespan from spring to late summer. Fecundity varies from tens to more than a hundred eggs per female. Full development is achieved in one or two years depending on climate and egg-laying date. Larvae and pupae overwinter inside their tunnels in wood.

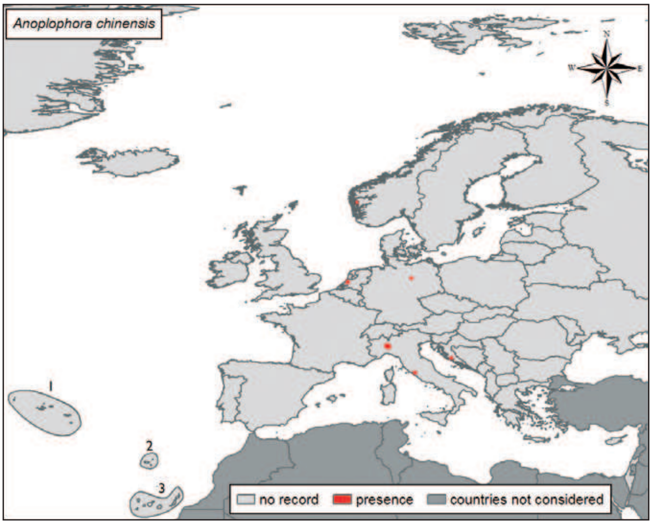
Native habitat (EUNIS code): G1- Broadleaved deciduous woodland; G5- Lines of trees, small anthropogenic woodlands.

Habitat occupied in invaded range (EUNIS code): G5- Lines of trees, small anthropogenic woodlands. Prefers subtropical to temperate climate; can survive in a large part of Europe.

Native range: East Asia (China, Taiwan, Korea, Japan, Myanmar, Vietnam).

Introduced range: Italy and a spot in the Netherlands (*Map*). First recorded in Lombardia, near Milano, Italy in 2000 but probably arrived several years earlier. Increasing frequency of interceptions during the last ten years in Europe. Eradicated in France and Great Britain. Italian populations from Lombardia recently spread in the peninsula, including the Roma area.

Credit: Franck Hérard



Pathways: Introduced with infested woody materials, especially bonsai plants.

Impact and management: Citrus longhorn beetle may disturb broadleaved forest ecosystems by selective tree killing or via direct/indirect competition with native xylophagous insects, including protected ones. Social impact occurs because in urban areas (streets, private and public gardens) the species kills trees and *Rosa* shrubs. This is one of the most destructive cerambycid pests of fruit orchards in its native range, especially on *Citrus* trees. Larval tunnels also depreciate harvested wood. This longhorn beetle is difficult to trap; surveys are generally based on visual detection of damage. Mechanical control involves destruction of infested trees by chipping or burning; trees can also be protected with fine wire meshes to prevent oviposition. Chemical control is of limited effect because the insects are deep within the tree, but systemic insecticides might be used. Biological control using natural enemies (parasitoid insects, entomopathogenic nematodes, fungi or bacteria) is under investigation but not yet being used.

Selected references

Colombo M, Limonta L (2001) *Anoplophora malasiaca* Thomson (Coleoptera Cerambycidae Lamiinae Lamiini) in Europe. Bollettino di Zoologia agraria e di Bachicoltura II Ser 33: 65–68.

EPPO (2010) *An*oplophora chinensis found again in the Netherlands. EPPO Reporting Services 2: 2010/025.

Hérard F, Ciampitti M, Maspero M, Krehan H, Benker U, Boegel C, Schrage R, Bouhot-Delduc L, Bialooki P (2006) *Anoplophora* species in Europe: infestations and management processes. *Bulletin OEPP/EPPO Bulletin* 36: 470–474.

14.7 – *Anoplophora glabripennis* (Motschulsky, 1853) - Asian longhorned beetle (Coleoptera, Cerambycidae)

Daniel Sauvard

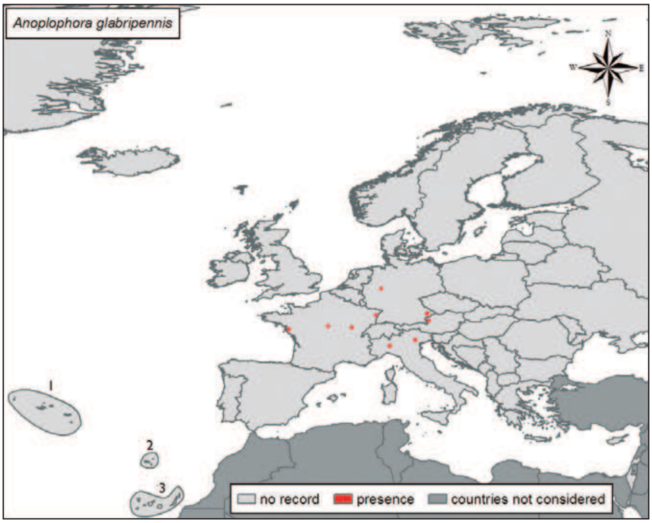
Description and biological cycle: Large, stout beetle, 20–35 mm long with jet-black body and white spotted elytra. Antennae longer than body, black with blue rings at segment base (*Photo up*). The larva is a legless grub up to 50 mm long when fully grown. It is creamy white in colour, with a chitinized brown mark on the prothorax (*Photo down*). *Xylophagous** species, feeding on a wide range of deciduous trees, mostly species with soft wood such as *Acer* or *Populus* where the larvae live inside the wood, in tree boles or large branches. Adults also eat bark on small branches. Adults fly up to 1.5 km from the emergence place. Possible human-mediated long-distance dispersal by infested wood movement or adults hitchhiking on vehicles. Eggs are laid throughout female life from spring to late summer; fecundity is variable from tens to more than a 100 eggs per female. Full development is achieved in one or two years depending on climate and oviposition date. Larvae and pupae overwinter inside wood tunnels.

Native habitat (EUNIS code): G- Broadleaved deciduous woodland; G5- Lines of trees, small anthropogenic woodlands.

Habitat occupied in invaded range (EUNIS code): G5- Lines of trees, small anthropogenic woodlands. Prefers subtropical to temperate climate; can survive in a large part of Europe up to S Sweden.

Native range: East Asia (China, Taiwan, Korea, Japan)

Credit: F. Hérard (above), Alain Roques (below)



Introduced range: USA, Canada, Austria, France, Germany, Italy (*Map*). Increasing frequency of interceptions and introductions in Europe during the last ten years. Where the species has been introduced, always in urban areas, eradication attempts have been undertaken.

Pathways: Introduced repeatedly with infested woody materials, especially wood packaging, pallets and waste materials.

Impact and management: May disturb European broadleaved ecosystems by selective tree killing or direct/indirect competition with native xylophagous insects, including protected ones. Social impact occurs because primary introduction is always in urban areas where the beetle weakens or kills trees in streets, private and public gardens. One of the most destructive cerambycid forest pests in its native range, inducing heavy damage in broadleaved stands, including poplar plantations. Larval tunnels also depreciate harvested wood. Difficult to trap; surveys generally based on visual detection of damage. Mechanical control involves destruction of infested trees by chipping or burning; trees can also be protected with fine wire mesh to prevent oviposition. Chemical control is of limited effect because the insects live deep within the tree; systemic insecticides may be tried. Biological control using natural enemies (parasitoid insects, entomopathogenic nematodes, fungi or bacteria) is under investigation but not yet used.

Selected references

Dauber D, Mitter H (2001) Das erstmalige Auftreten von *Anoplophora glabripennis* Motschulsky 1853 auf dem europaïschen Festland (Coleoptera: Cerambycidae: Lamiinae). Beiträge zur Naturkunde Oberösterreichs 10: 503–508.

Haack RA, Hérard F, Sun JH, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorn beetle: A worldwide perspective. Annual Review of Entomology 55: 521–546.

Hérard F, Maspero M, Ramualde N, Jucker C, Colombo M, Ciampitti M, Cavagna B (2009) *Anoplophora glabripennis* - Eradication programme in Italy (April 2009). http://www.eppo.org/QUARANTINE/anoplophora_glabripennis/ANOLGL_IT.htm.

14.8 – *Diabrotica virgifera virgifera* LeConte, 1868 - Western corn rootworm (Coleoptera, Chrysomelidae)

Wolfgang Rabitsch

Description and biological cycle: Small beetle, 5–6 mm long, with pale greenish-yellow body (*Photo*). Larvae are wrinkled, yellowish-white, with a brown head capsule. The Western corn rootworm is a major crop pest on maize (*Zea mays*), repeatedly introduced to Europe from North America in the early 1990s, which spreads rapidly. Adult flight dispersal is 20–100 km per year; intercontinental dispersal occurs via the transfer of goods. Up to 1000 eggs are produced per female during lifespan, laid preferentially in the soil at the base of maize plants. Larvae develop in and on roots of the food plant and adults move upwards and feed on the plant. The species develops as one generation per year. Eggs overwinter in diapause.

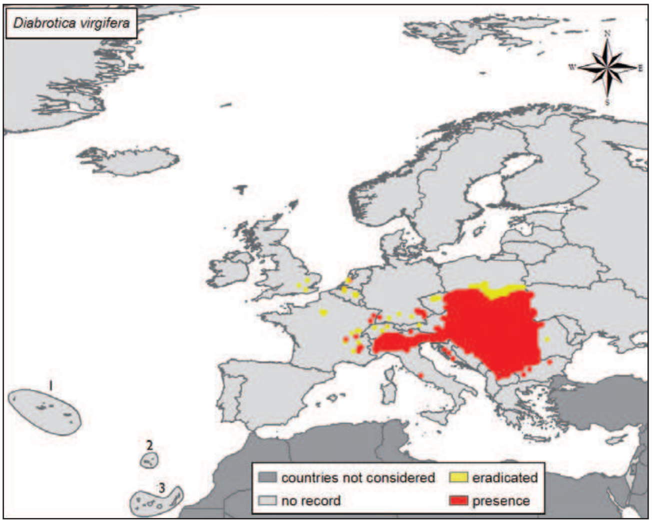
Native habitat (EUNIS code): E- Grassland.

Habitat occupied in invaded range (EUNIS code): I: Regularly or recently cultivated agricultural, horticultural and domestic habitats; I1- Arable land and market gardens. Temperature not only influences larval development, but also triggers flight activity which governs the rate of dispersal. Increased habitat diversity slows the rate of spread.

Native range: Probably in the tropics and subtropics of Mexico and Central America.

Introduced range: North America, Europe (Serbia 1992; Croatia, Hungary 1995; Romania 1996; Bosnia and Herzegovina 1997; Bulgaria, Italy, Montenegro 1998; Slovakia, Switzerland 2000; Ukraine 2001; Austria, Czech Republic, France 2002; Belgium, Netherlands, Slovenia, UK 2003; Poland 2005; Germany 2007; *Map*). Genetic data provides evidence for

Credit: Margarita Auer



repeated introductions from America (Ciosi et al 2008). Spread in Europe continues and the species is expected to colonize all maize producing countries in Eurasia.

Pathways: Repeatedly transported via vehicles (airplanes, railways, ships).redit : Margarita Auer

Impact and management: Ecosystem impacts including side-effects on non-target species as a consequence of insecticide treatment or biological control are possible, but not demonstrated. This species is regarded as one of the most serious pest species of corn in the USA and its damage to crops and chemical control amounts to 1 billion US$ per year. Current economic damage in Europe is restricted to some countries, but there is clearly a time lag of several years between the first record and economic damage. Predictive models forecast an economic impact of about 500 million €/year in Europe. Crop rotation is the most feasible preventative measure, although crop rotation resistant rootworm variants are known in the USA. Monitoring the spread of adults via pheromone-traps is used as a predictor of damage and further treatment is applied in the following season. Chemical control involves several toxicants applied as granular soil insecticides against the larvae and by aerial spraying against adults (spraying is not permitted in most European countries). Biological control using natural enemies (tachinid flies, nematodes, entomopathogenic fungi) is currently under investigation.

Selected references

Ciosi M, Miller NJ, Kim KS, Giordano R, Estoup A, Guillemaud T (2008) Invasion of Europe by the western corn rootworm, *Diabrotica virgifera virgifera:* multiple transatlantic introductions with various reductions of genetic diversity. Molecular Ecology 17: 3614–3627.

Kuhlmann U, van der Burgt W (1998) Possibilities for biological control of the western corn rootworm, *Diabrotica virgifera virgifera* LeConte, in Central Europe. BioControl 19, 59–68.

Vidal S, Kuhlmann U, Edwards CR (2004) Western Corn Rootworm: Ecology and Management. CABI Bioscience, Delémont, 320 pp.

14.9 – *Epitrix hirtipennis* (Melsheimer, 1847) - Tobacco flea beetle (Coleoptera, Chrysomelidae)

Rumen Tomov

Description and biological cycle: Adult about 1.5–2 mm long, brown (*Photo left*). Elytra the same colour as pronotum except on their central areas which are almost black; with rows of fine, distinct punctures, and scattered thin, relatively short brown-yellow setae. Eggs tiny, elongate and white. Fully developed larvae about 4–5 mm long with slender, cylindrical, whitish body and brown head. Pupae white turning darker with anterior end curved downwards. The tobacco leaf beetle is oligophagous on plants of the family Solanaceae: tobacco (*Nicotiana tabacum*), potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), aubergine (*Solanum melongena*), pepper (*Capsicum annuum*), ground cherry (*Physalis pruinosa*), jimson weed (*Datura stramonium*) and horsenettle (*Solanum carolinense*). Overwinters as adult among debris around fields of host plants or in tobacco seedbeds. Activity resumes in spring feeding on weedy hosts until crop hosts are available. Females lay eggs in the soil near the host plants, which hatch after a week. Larval development lasts 3–4 weeks. Pupal period is 7–10 days, before new generation of beetles emerges. The species develops 3–4 generations per year. Damage is caused by both larvae and adults. Adult beetles feed mainly on leaves in which they produce small round holes (*Photo left*). The larvae burrow into the soil, living in the roots or tunneling into the stalk (*Photo right*).

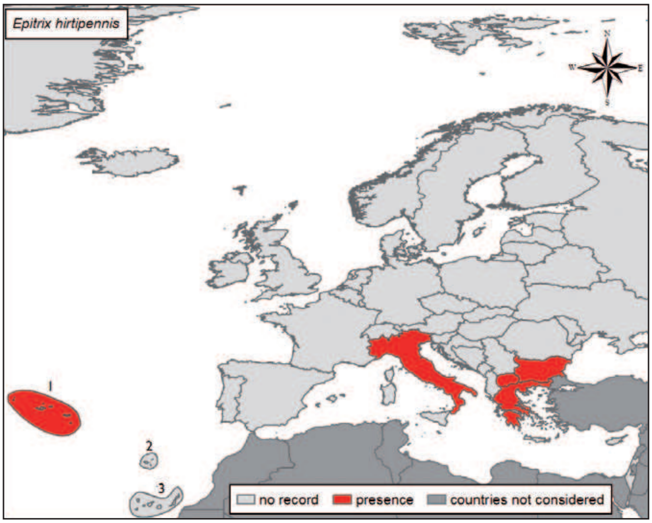
Native habitat (EUNIS code): E- Grassland and tall forb habitats.

Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural and domestic habitats. The species can also feed on weedy Solanaceae and, thus, is able to invade various types of habitats.

Native range: North America, Canada, Continental US, Mexico

Introduced range Recorded for the first time in 1984 in southern Italy; then spread in the Balkans (Map) and Turkey. Also present in the archipelago of the Azores and of Pacific Ocean (French Polynesia - Tahiti, Hawaii).

Credit: Rumen Tomov



Pathways : The main mode of introduction and spread is the transport of infested plant material. Adults fly actively between fields.

Impact and management: No ecological impact has been reported so far. The species is mainly known as a serious pest of tobacco. It is most dangerous early in the growing season for young seedlings in plant beds. The plants often die after being transplanted into the field. Numerous holes on leaves of mature plants and the adults' excrement delay the growth of plants and reduce the quality and value of tobacco leaves. In heavy infestations, the plant may be totally defoliated like lacework. Both types of attack reduce plant vigour and value, and may ruin an entire plant bed. The pest has been suggested as a vector of Tobacco ringspot nepovirus, which causes significant disease in tobacco. It may also damage potato, aubergine and tomato. Monitoring seedlings is important for early detection of flea beetles. Chemical control involves a number of insecticides for plant bed and the field situations. Biological control using *Bacillus thuringiensis* ssp. *tenebrionis* on adults may represent a suitable alternative. Possible cultural control practices include the sterilization or fumigation of top soil before planting and removal of weedy vegetation and excess organic debris in surrounding areas.

Selected references

Deseo KV, Balbiani A, Sannino L, Zampelli G (1993) Zur Biologie und biologischen Bekampfung des Tabakkafers, *Epitrix hirtipennis* Melsh. (Col., Chrysomelidae) in Italien. Anzeiger fuer Schaedlingskunde Pflanzenschutz Umweltschutz 66: 26–29.

Lykouressis DP, Mentzos G, Parentis A (1994) The phenology of *Epitrix hirtipennis* (Mels.) (Col., Chrysomelidae) and damage to tobacco in Greece. Journal of Applied Entomology 118: 245–252.

Paparatti B, Scubla P (1994) A contribution to the study of the bioethology of *Epitrix hirtipennis* (Melsheimer) (Coleoptera, Chrysomelidae). Frustula Entomologica 17: 175–184.

14.10 – *Leptinotarsa decemlineata* Say, 1824 - Colorado potato beetle (Coleoptera, Chrysomelidae)

Carlos Lopez-Vaamonde

Description and biological cycle: Adults up to 11 mm long; elytra yellow with ten characteristic black longitudinal bands (*Photo*). Main natural spread of beetle over large areas is by wind-borne migration. Females usually deposit eggs on the underside surface of host plant leaves. An egg mass may contain 10–40 eggs. Most adult females deposit over 300 eggs during 4–5 weeks, but they can lay up to 800 eggs. Potatoes are the preferred host, but the Colorado potato beetle (Colorado beetle) may feed and survive on a number of other Solanaceae: eggplant, tomato, pepper, tobacco, ground cherry, horse-nettle, common nightshade, *Belladonna*, thorn apple, henbane, and its first recorded host plant: buffalo-bur, *Solanum rostratum*. Larvae are hardy and resistant to unfavourable weather.

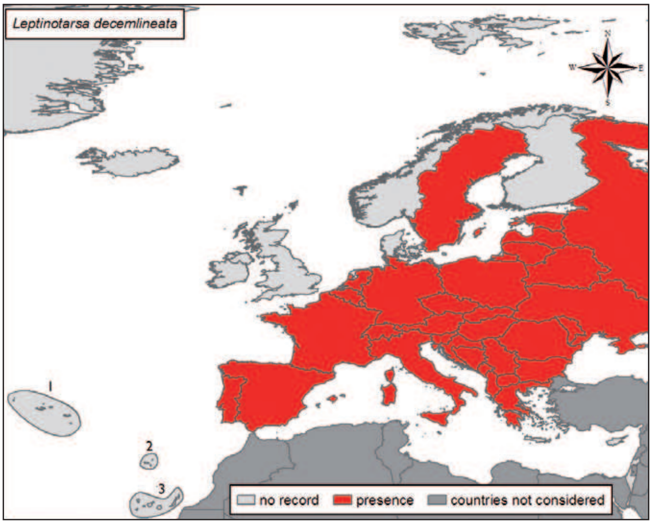
Native habitat (EUNIS code): G1- Broadleaved deciduous woodland.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks. Beetles are sensitive to cold temperatures. They need at least 60 days of temperature over 15 °C in summer and winter temperatures not falling below 8 °C.

Native range: Mexico, where beetles are still present and feed on wild Solanaceae such as *Solanum rostratum.*

Introduced range: beetles were accidentally introduced into USA. In 1922, the species was introduced to France from where it expanded almost throughout the European continent (*Map*) and to parts of Asia in about 30 years. Capable of adapting to different climatic

Credit: György Csóka



conditions and different host plants, this beetle is constantly moving to new areas. Its distribution is limited by temperature and therefore climate warming could further expand its distribution range.

Pathways: International trade appears to be the most likely pathway for introduction on imported commodities such as fresh vegetables from infested areas. Beetles can also be spread through wind and attachment to all forms of packaging and transport.

Impact and management: Serious pest of potatoes. Both adults and larvae feed on potato leaves and damage can greatly reduce potato yields. Beetles can also be a pest of other solanaceous plants such as tomato, aubergine, tobacco and peppers. This beetle may be managed culturally by crop rotation. Mechanical control involving destruction of crop debris is very effective at reducing population levels. Chemical control commonly involves insecticides, but resistance to them develops rapidly. Biological control includes a long list of natural enemies. *Bacillus thuringiensis* and some species of nematodes have particularly been used as control agents.

Selected references

CABI/EPPO (1997) Quarantine pests for Europe, 2nd Ed. Wallingford, UK: CAB International.

Grapputo A, Boman S, Lindström L, Lyytinen A, Mappes J (2005) The voyage of an invasive species across continents: genetic diversity of North American and European Colorado potato beetle populations. Molecular Ecology 14: 4207–4219.

Pucci C, Dominici M, Forcina A (1991) Population dynamic and economic threshold of *Leptinotarsa decemlineata* (Say) (Col., Chrysomelidae) in Central Italy. Zeitschrift für Angewandte Entomologie 111: 311–317.

14.11 – *Harmonia axyridis* (Pallas, 1773) - Harlequin ladybird (Coleoptera, Coccinellidae)

Helen Roy and David Roy

Description and biological cycle: Polyphagous predatory ladybird, 5–8 mm long, variable in colour pattern (yellow to orange to black) with a variable number of spots (0–21) (*Photo-adults mating*). Highly dispersive, flying readily between host plants during breeding periods. This species migrates long distances in Asia and America. 20–50 eggs are produced per day, 1000–4000 in their lifetime. Adults typically live for a year, reproducing for three months. The Harlequin ladybird is generally bivoltine but can produce four generations per year in favourable conditions (Majerus *et al*. 2006).

Native habitat (EUNIS code): G- Woodland, forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): Same range of habitats as in the native range as well as G3- Coniferous woodland; G5- Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; and, J1- Buildings of cities, towns and villages. The wide native range in Asia shows that the species can reproduce in both warm and cool climates and is well adapted to temperature extremes.

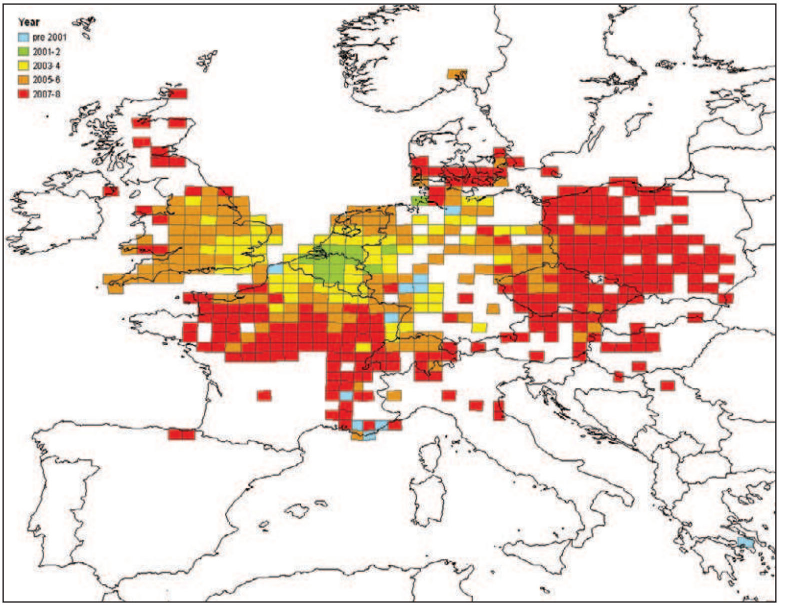
Native range: Central and Eastern Asia.

Introduced range: America, South Africa, Egypt, Europe (Brown *et al*., 2008). Increasing trend (*Map;* from Brown et al 2008, modified).

Pathways: *Harmonia axyridis* was introduced intentionally as a biocontrol agent of aphids and unintentionally in horticultural/ornamental material.

Impact and management: Potential to effect biodiversity, particularly that of other aphidophages and non-pest insects, through resource competition, intraguild predation and direct intra-specific competition. This beetle is also a pest of orchard crops (apples and pears) because as aphids become scarce in autumn, *H. axyridis* feeds on soft fruit, causing blemishing

Credit: Helen Roy



and an associated reduction in the market value. A tendency to aggregate in bunches of grapes prior to harvest makes the ladybirds difficult to separate from the fruit and so they are sometimes processed during wine making. Alkaloids contained within these beetles adversely affect the taste of the vintage.

The beetle's propensity to swarm and its large winter indoors aggregations are regarded as a nuisance. Economic impact is mainly on the wine industry, with reduction in fruit quality and management measures required in domestic dwellings (Kenis *et al*., 2008). Preventing the use of *H. axyridis* as a biocontrol agent and ensuring that fruit and cut flower imports are clean will reduce introduction events. Invasion into households can be limited by covering entrances with fine mesh. Adults and late instar larvae can be removed from unwanted locations manually, e.g., using a vacuum cleaner. Light traps can attract adults but the efficiency of these is not yet quantified. Chemical control in field situations such as orchards and vineyards is not applicable because of the impact of insecticides on other aphidophages and beneficial insects (Kenis et al., 2008).

Selected references

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, Hagg T, Kenis M, Klausnitzer BEM, Kovar I, Loomans AJ, Majerus MEN, Nedved O, Pedersen J, Rabitsch W, Roy HE, Ternois V, Zakharov I, Roy DB (2008) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. BioControl, 53: 5–22.

Kenis M, Roy HE, Zindel R, Majerus MEN (2008) Current and potential management strategies against *Harmonia axyridis*. BioControl, 53: 235–252.

Majerus MEN, Strawson V, Roy HE (2006) The potential impacts of the arrival of the Harlequin ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), in Britain. Ecological Entomology, 31: 207–215.

14.12 – *Gonipterus scutellatus* Gyllenhal 1833 - Eucalyptus snout beetle (Coleoptera, Curculionidae, Cyclominae)

Daniel Sauvard

Description and biological cycle: Medium-sized weevil species (12–14 mm), grey to brown with a light transverse band on the elytra and pale brown hairs (*Photo left- adult on eucalyptus branch*). This species is morphologically very similar to another Australian eucalyptus weevil, *G. gibberus*, invasive too but not present in Europe at this time. Hosts are different *Eucalyptus* species. The weevil has several generations per year (generally two in southern Europe). The adults emerge from the soil and feed on leaves (*see Figure 8.2.6 in Chapter 8*) and growing shoots. Throughout their life, females lay several egg batches protected by brown capsules on surfaces of young leaves (overall fecundity of a female is about 150–300 eggs). Yellowish-green larvae feed on leaves (*Photo right- larval damage*) and twigs, then fall on the ground and pupate in the soil. Overwintering occurs in the adult stage.

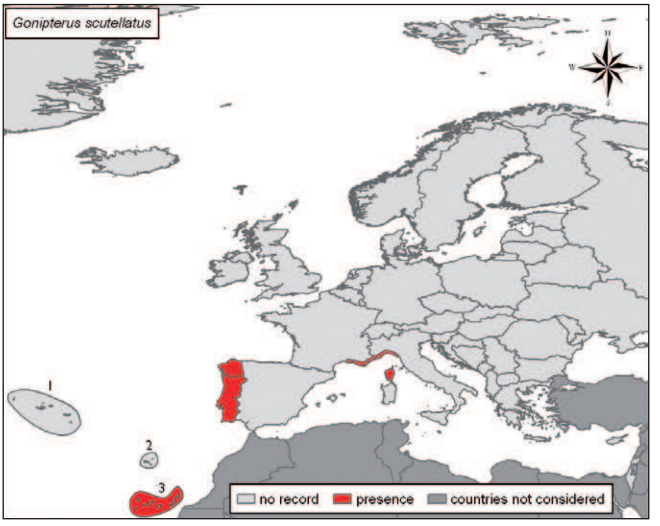
Native habitat (EUNIS code): G2- Broadleaved evergreen woodland.

Habitat occupied in invaded range: G2- Broadleaved evergreen woodland; G5- Lines of trees, small anthropogenic woodlands; I2- Cultivated areas of gardens and parks; X- parks and gardens.

Native range: Southeastern Australia.

Introduced range: Progressively introduced in all places where eucalyptus have been introduced: USA, South America, Western Australia, New Zealand, China, South and East Africa. In Europe, the Eucalyptus snout beetle was first recorded in Italy in 1990 and then in other Mediterranean countries (*Map*).

Credit: Alain Roques



Pathways: Adults, eggs and larvae can be transported with live eucalyptus; larvae and pupae can be transported with soil. The adults can fly to disperse locally; adult may hitch-hike, e.g. on vehicles.

Impact and management: This weevil is an important eucalyptus pest in all areas where it has been introduced. Adults and especially larvae damage eucalyptus leaves, mainly young ones. Larvae characteristically damage only one surface of leaves, while adults chew the edge. Defoliation causes growth reduction, and even tree mortality in case of successive severe damage. Young trees are generally the most damaged. Susceptibility depends of *Eucalyptus* species; in Europe, the commonly planted *E. globulus* is one preferred host. Chemical control is not recommended due to side effects on honey bees often visiting eucalytus flowers. Biological control has been successfully achieved in several world and European countries using the Australian chalcid *Anaphes nitens* (Girault 1928) (Hymenoptera, Mymaridae), an egg parasitoid.

Selected references

Arzone A (1976) Un nemico dell'Eucalipto nuovo per l'Italia. Apicoltore Moderno 67: 173–177.

Mansilla JP, Pérez Otero R (1996) El defoliador del eucalipto *Gonipterus scutellatus*. Phytoma España 81: 36–42.

Rabasse JM, Perrin H (1979) Introduction en France du charançon de l'eucalyptus, *Gonipterus scutellatus* Gyll. (Col., Curculionidae). Annales de Zoologie, Écologie Animale 11: 336–345.

14.13 – *Rhopalapion longirostre* (Olivier 1807) (= *Apion longirostre*) - Hollyhock weevil (Coleoptera, Apionidae)

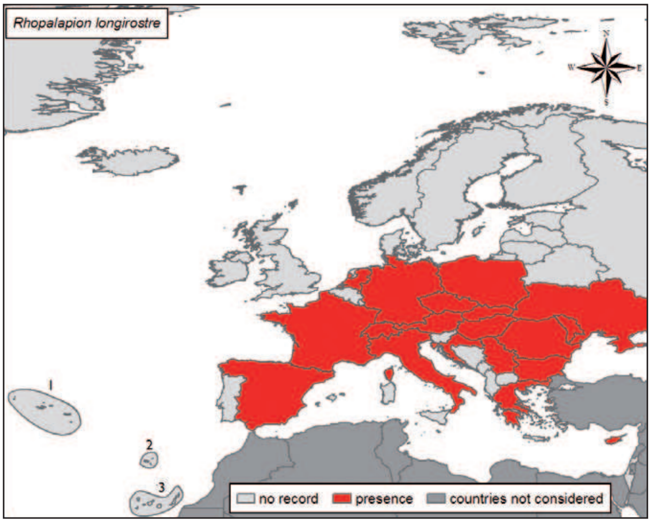
Katalin Tuba and Ferenc Lakatos

Description and biological cycle: Small weevil species distinguished from other *Apion* and *Aspidapion* species by its orange legs and enormously narrow *rostrum** (*Photo- adults mating on Alcea leaf*) The females have one of the longest rostra among all Middle-European Apionidae, longer than half the remaining body length which is 3–3.5 mm. Their black or rarely yellowish antennae are located halfway along this snout. The greyish-black body is densely hairy. Hosts are different *Alcea* species, especially *A. rosae* (Malvaceae). It develops on hollyhock with other host specialist Apionidae species, like *Aspidapion aeneum, A. radiolus* and *Alocentron curvirostre.* The hollyhock weevil has one generation per year. The adults overwinter under fallen leaves or in the soil around the stem. In spring the adults come out and chew the leaves, the petioles and the stem. The females lay eggs at the bottom of the buds or on young ornamental or herbaceous plants. The larvae develop by chewing seeds and sometimes leaf tissue. Adults emerge from the seeds in August-September.

Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land; I: Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I2 - Cultivated areas of gardens and parks.

Credit: Ferenc Lakatos



Native range: Temperate Asia.

Introduced range: First detected in 1875 in Romania. Then, observed in most of the Mediterranean and Central-European countries (*Map*). Also introduced in North America since 1914 in Georgia.

Pathways: Probably trade of ornamentals.

Impact and management: This species can spread very quickly due to its distinct habit and special host plant especially in urban gardens. It can cause serious ecological damage in hollyhock cultivation as ornamentals or herbs. Both chemical and biological control is possible against this insect. However application is recommended mainly in production circumstances rather than garden situations.

Selected references

Ehret JM (1983) *Apion* (*Rhopalapion*) *longirostre*, espèce nouvelle pour la France (Coleoptera, Curculionidae). L'Entomologiste 39: 42.

Kozłowski MW, Knutelski S (2003) First evidence of an occurrence of *Rhopalapion longirostre* in Poland. Weevil News 13: 4 pp. http://www.curci.de/Inhalt.html.

Perrin H (1984) Présence en France d'*Apion* (*Rhopalapion*) *longirostre* (Olivier) (Coleoptera, Curculionidae, Apioninae) et répartition dans la région paléarctique. L'Entomologiste 40: 269–274.

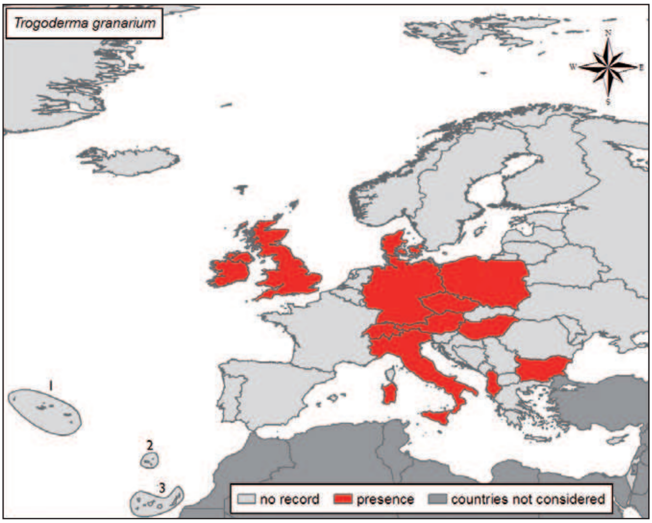
14.14 – *Trogoderma granarium* (Everts, 1898) (= *T. khapra* (Arrow, 1917)) (= *T. afrum* (Priesner, 1951)) - Khapra beetle (Coleoptera, Dermestidae)

Katalin Tuba and Ferenc Lakatos

Description and biological cycle: Adults of this tiny beetle species are ovate and densely haired (*Photo- Adult, larva, larval skins and damage to wheat grains*). Males are 1.4–2.3 mm long and 0.75–1.1 mm wide, while females are slightly larger and lighter in colour. Head and pronotum are dark reddish-brown, while elytra are reddish brown with two or three lighter, indistinct bands. Legs are yellowish-brown. Antennae consist of 10–11 segments; the last 3–4 segments at females and the last 5 segments at males forming a club. Antennae are yellowish-brown. Eggs are 0.7 mm long and 0.25 mm wide, cylindrical, milky white, turning pale yellowish with age. At the end of the embryonic development, six brown bands are visible in the eggs. Generally there are 6–8 larval stages, but under unfavourable development conditions, up to 10–12. A tail on the last abdominal segment is half of the whole larval body length. Larval body is yellowish-white with brown head and setae. Mature larva is 4–6 mm long and 1.5 mm wide. Male pupa is 3.5 mm long and female 5 mm, both sexes yellowish-brown and hairy. The khapra beetle has one to nine generations per year depending on nutritional resources, temperature, humidity, light and season. Each female lays a total of 50–100 eggs on host material. Development time varies between 26–220 days. Egg stage takes 3–14 days, while larvae live 4–6 weeks. Larvae can enter diapause if the temperature falls below 25°C and may remain in this condition for many years. The pupa stage takes 2–5 days. Adult khapra beetles have wings, but are not known to fly and feed very little. Mated females live from 4–7 days, unmated females from 20–30 days, and males from 7–12 days.

Habitat occupied in invaded range (EUNIS code): J- Constructed, industrial and other artificial habitats.

Credit: Ministry of Agriculture and Regional Development Archives of Hungary, bugwood.org



Native range: India.

Introduced range: all over the word except for Australia and New Zealand. Warmer climates are preferred, living in stores further north. The khapra beetle first moved into Europe in 1908. At first the eradication was successful but during the First World War, the species was introduced again and became established.

Pathways: The wide geographical distribution of this pest is to a certain extent due to human activities. In the absence of flight, its spread is dependent on movement of infected goods. The species can spread with containers in which it diapauses.

Impact and management: This polyphagous species is one of the most important and dangerous insect pest of the stored products. The gregarious larvae damage both quality and quantity of stored foodstuff, chewing seeds, while adults cause negligible damage. Food produce attacked includes grain and cereal (wheat, barley, oats, rye, maize, rice, flour, pasta) as well as beans, herbs, chocolates, nuts and many other products. Both physical and chemical control can be used against this insect but it is one of the most difficult detritivorous pests to manage. Established infestations are difficult to control and eradicate because the larva can live without food for long time and it can crawl and slip into tiny cracks and crevices, and is resistant towards many insecticides.

Selected references

Harris DL (2006) *Trogoderma granarium* Everts (Insecta: Coleoptera: Dermestidae). http://entnemdept.ufl.edu/creatures/urban/beetles/khapra_beetle.htm. [accessed 25 February 2010].

Jenser G., Mészáros Z, Sáringer Gy (Eds) (1998) A szántóföldi és a kertészeti növények kártevői. Mezőgazda Kiadó Budapest: 157–158.

Szőnyegi S, Kalmár K (1999) Szemestermény tárolók károsítói és az ellenük való védekezés. Agroinform Kiadó Budapest: 49–50.

14.15 – *Diocalandra frumenti* (Fabricius, 1801) - Four-spotted coconut weevil (Coleoptera, Dryophthoridae)

Wolfgang Rabitsch

Description and biological cycle: Curculionid beetle, shiny black with four large red to brown spots on the elytra. Length of adults is 6–8 mm. Larvae bore galleries in roots, petioles, inflorescences and fruits of palms, where they pupate (*Photo left- pupal chambers in a palm frond*). Adult emergence is noticed by round holes (*Photo right- Adult emerging from a palm tree and emergence holes*) The whole life-cycle takes 10–12 weeks. Larvae cause premature yellowing and collapse of palm fronds as well as shedding of fruits and may cause the death of the tree. This weevil causes damage to many palm species, including economically important and ornamental species (*Cocos nucifera, Phoenix dactylifera, P. canariensis* and *Elaeis guineensis*).

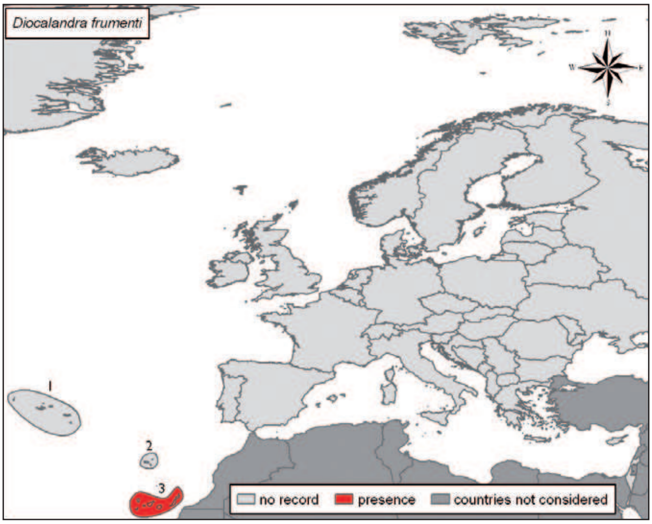
Native habitat (EUNIS code): G2.5- Palm groves.

Habitat occupied in invaded range (EUNIS code): G2.5- Palm groves; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Native range: Southeast Asia.

Introduced range: In Europe, it was found in the south of Gran Canaria, the Canary Islands, in 1998, on the endemic palm *Phoenix canariensis*. It has also established on the islands of Tenerife, Lanzarote and Fuerteventura, where it occurs in several protected areas. Also intro-

Credit: EPPO



duced in South Asia (Bangladesh, India, Indonesia, Malaysia, Philippines, Sri Lanka, Taiwan, Thailand), Japan (Ryukyu), East-Africa, Madagascar, Seychelles, Oceania (Australia, Guam, Palau, Papua New Guinea, Samoa, Solomon Islands, Vanuatu), and South America (Ecuador).

Pathways: Probably with ornamental trade

Impact and management: Introduction occurs with infested ornamental palm trees. *D. frumentii* is a threat to native Canary Islands Date Palm and it may change the fire regime and the structure, abundance and succession of invaded habitats. Detection and control is difficult due to the secretive life habit.

Selected references

González Núñez M, Jiménez Álvarez A, Salomones F, Carnero A, Del Estal P, Esteban Durán JR (2002) *Diocalandra frumenti* (Fabricius) (Coleoptera: Curculionidae), nueva plaga de palmeras introducida en Gran Canaria. Primeros estudios de su biología y cría en laboratorio. Boletín de Sanidad Vegetal Plagas, 28(3): 347–355.

Samarin Bello CR (2008) *Diocalandra frumenti* (Fabricius, 1801). In: Silva L, Ojeda Land E, Rodríguez Luengo JL (Eds) Invasive Terrestrial Flora & Fauna of Macaronesia. Top 100 in Azores, Madeira and Canaries. ARENA, Ponta Delgada, pp. 418–420.

14.16 – *Rhynchophorus ferrugineus* (Olivier, 1790) - Red Palm Weevil (Coleoptera, Dryophthoridae)

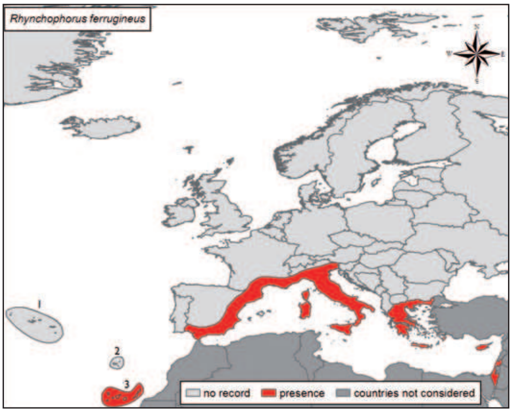
Wolfgang Rabitsch

Description and biological cycle: Curculionid beetle, reddish-brown, with dark spots on elytra (*Photo- see also Figure 8.2.7a in Chapter 8*). Length of adults is 3.5 cm, length of larvae 5 cm. Females bore small holes in the trunk of a palm tree and lay up to 300 eggs. Grub-like larvae (*see Figure 8.2.7b in Chapter 8*) feed on soft tissues inside the host plant, producing long tunnels up to 1 m inside the trunk. Pupation takes place at the base of the palm. Completion of the life-cycle takes four months. Feeding activity of larvae can completely destroy palms. The diurnal adults search for new palms and can fly distances up to 1 km. Long-distance dispersal happens via infested palm trees. Host plants are different palm tree species. According to EU-Decision 2007/365/EC, susceptible host plants, other than fruit and seeds, having a diameter of the stem at the base of over 5 cm are *Areca catechu, Arenga pinnata, Borassus flaellifer, Calamus merillii, Caryota maxima, C. cumingii, Cocos nucifera, Corypha gebanga, C. elata, Elaeis guineensis, Livistonia decipiens, Metroxylon sagu, Oreodoxa regia, Phoenix canariensis, P. dactylifera, P. theophrasti, P. sylvestris, Sabal umbraculifera, Trachycarpus fortunei* and *Washingtonia* spp. The weevil was also found in *Agave americana*, *Brahea armata*, *Butia capitata*, *Howea firsteriana* and *Saccharum officinarum*.

Native habitat (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; X24- Domestic gardens of city and town centres; X25- Domestic gardens of villages and urban peripheries.

Credit: Olivier Denux



Native range: South(east)-Asia

Introduced range: *R. ferrugineus* has been introduced in most of Mediterranean countries and islands of Europe (*Map*). Since its first discovery in Spain (Andalucía and Valenciana, 1994) it colonized Italy (2004, incl. Sardegna, Sicilia), the Canary Islands (2005), Mallorca (2006), France (incl. Corsica), Greece, Cyprus (2006), Malta, Portugal (2007), Albania (2009) and Ceuta (2009). It also occurs in the Eastern Mediterranean region (Turkey, Syria, Israel, Jordan, Egypt) and North Africa (Morocco). Also introduced to Oceania (Australia?, Papua New Guinea, Solomon Islands), China, the Near and Middle East, and the Caribbean (Netherlands Antilles).

Pathways: Probably ornamental trade of palm trees

Impact and management: Symptoms are visible only late after colonization of the beetle and usually palms do not recover when symptoms become visible (*see Figure 8.2.7c in Chapter 8*). Early detection is difficult, as symptoms of infested palms remain unnoticed for several years. EU-Decision 2007/365/EU requires phytosanitary certificates for palm imports and eradication measures at infested areas. Imported palms needs to be kept in quarantine for inspection. This also is recommended for another *Rhynchophorus* species, *R. palmarum*, listed by EPPO as A1 species, not yet introduced to Europe, but presenting a similar phytosanitary risk to palms. Infected palms must be cut and burned or buried deeply. IPM employs pheromone traps to monitor and collect beetles. Removal of offshoots, which are preferred oviposition sites, is not recommended, because wounds attract females to oviposit. Also pruning of palm leaves should be carried out in winter, as pruning attracts beetles and facilitates egg laying. It is estimated that more than 30.000 palm trees have been destroyed in Spain within three years.

Selected references

Barranco P, de la Pena J, Cabello T (1996) El picudo rojo de las palmeras, *Rhynchophorus ferrugineus* (Olivier), nueva plaga en Europa (Col., Curculionidae). Phytoma-Espana 76: 36–40.

Faleiro JR (2006) A review on the issues and management of red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. International Journal of Tropical Insect Science 26: 135–154.

Liu G, Peng ZQ, Fu YG (2002) Research advances on the red palm weevil *Rhynchophorus ferrugineus*. Journal of Tropical Agricultural Science 22: 73–77.

14.17 – *Megaplatypus mutatus* (Chapuis, 1865) - The grand forest borer (Coleoptera, Curculionidae, Platypodinae)

Massimo Faccoli

Description and biological cycle: Adult females 8–9 mm long, males slightly smaller (7.5 mm). Body brown above and reddish-yellow below, with reddish tarsi and antennae (*Photo*). Elytrae of males with *sulcate** striae and characteristic spiniform processes on the *declivity**; female elytral declivity rounded and without processes. Mature larvae about 7.2 mm long. *M. mutatus* bores 3 mm-wide holes in the trunk, approximately 4 m above ground level. Adults excavate long and sinuous galleries that become covered by the black mycelium of symbiotic fungi, which nourish larval instars. Unlike other ambrosia beetles, *M. mutatus* attacks standing and vigorous trees. The stem attack does not kill the plant immediately, and the same tree may be re-infested several times by subsequent generations. *M. mutatus* infests mainly poplars (*Populus* spp.), willows (*Salix* spp.) and important fruit trees species such as apples (*Malus* spp.), walnuts (*Juglans* spp.) and avocados (*Persea* spp.). The species has been recorded also on *Acer, Citrus, Eucalyptus, Fraxinus, Laurus nobilis, Magnolia grandiflora, Platanus, Prunus, Quercus, Robinia pseudacacia, Tilia* and *Ulmus*.

Credit: G. Allegro, CRA Istituto di Sperimentazione per la Pioppicoltura, Casale Monferrato, eppo.org

Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland; G2 - Broadleaved evergreen woodland.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; I2 - Cultivated areas of gardens and parks.

Native range: subtropical and tropical areas of South America. The weevil has extended its range into temperate regions, reaching as far south as Neuquén in Argentinean Patagonia.

Introduced range: recently introduced and acclimatized in the Napoli region, Italy (2000) (*Map*). Adult flight can ensure species dispersal over short distances.

Pathways: Man-mediated long-distance dispersal is possible by international trade of infested woody plants and woody materials.

Impact and management: *M. mutatus* represents a threat for many woody species widely cultivated in Europe for commercial or ornamental purpose. It is a primary pest in commercial poplar plantations, especially those of *P. deltoides*. In Italy, damage has been recorded also on fruit trees (*Corylus avellana, Prunus cerasus, Pyrus communis* and *Malus domestica*). The damage is caused by adults, which bore large gallery systems into living host-trees. The galleries and associated fungi degrade the lumber and weaken the tree stems, which often then break during windstorms. As most of the life cycle is accomplished within wood tissues, this species is difficult to detect and to control, although some chemicals are available. Recent applications of the mating disruption technique are giving promising results.

Selected references

Tremblay E, Espinosa B, Mancini D, Caprio G (2000) Un coleottero proveniente dal Sudamerica minaccia i pioppi. L'informatore Agrario 48: 89–90.

14.18 – *Gnathotrichus materiarius* (Fitch, 1858) - American Utilizable Wood Bark Beetle (Coleoptera, Curculionidae, Scolytinae)

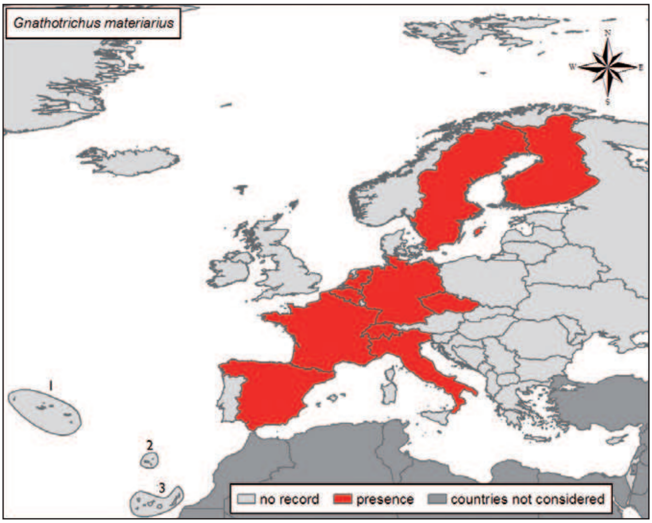
Massimo Faccoli

Description and biological cycle: Small species, 3.2–3.5 mm long, with a cylindrical, narrow and elongated body (*Photo*). Elytra dark reddish, generally smooth with only few short bristles on the declivity. Pronotum black and very fine punctured, except at the front where there are several granules. Head blackish and smooth, antennae with *funicle**5-segmented and club with two round sutures. Anterior coxae fused. This weevil is polyphagous on conifer trees, in Europe being recorded on *Pinus*, *Abies*, *Picea*, *Larix* and *Pseudotsuga*. *Gnathotrichus materiarius* is an ambrosia beetle excavating timber galleries 1mm in diameter and 10–15 cm long. The galleries host the black fungus *Endomycopsis fasciculata* Batra, which nourishes the larvae. In Central Europe, the adults fly between April and the middle of June, but it is possible that a second flight takes place at the end of the summer. The species is monogamous, but males are very rare. Mature larvae or young adults overwinter in their galleries.

Native habitat (EUNIS code): G3- Coniferous forests.

Habitat occupied in invaded range (EUNIS code): G3- Coniferous forests.

Credit: Louis Michel Nageilesen



Native range: North America

Introduced range: Since its first discovery in 1933 in France, this weevil has invaded a large part of Central, Western, Central and Northern Europe (*Map*). Man-mediated long-distance dispersal is possible by infested wood movement.

Pathways: Trade of trees or timber.

Impact and management: This species may disturb forest ecosystems by direct/indirect competition with native xylophagous insects. Typically a secondary species, recorded only on trees already felled or killed by other bark beetles. However, infestations reduce timber value because of damage from adult galleries and black discolouration caused by associated ambrosia fungi. Control is usually not required. Population monitoring may be based on visual detection of damage and by pheromone traps. Mechanical control may consist in the destruction of infested trees by chipping or burning. Natural enemies (parasitoid insects, entomopathogenic nematodes, fungi or bacteria) for possible biological control are under investigation but not yet being used. Chemical control has limited effect because the insects live deep within wood.

Selected references

Balachowsky A (1949) *Coléoptères Scolytides*. Faune de France 50. Paris: Librairie de la faculté des sciences. 320 pp.

Faccoli M (1998) The North American *Gnathotrichus materiarius* (Fitch) (Coleoptera Scolytidae): an ambrosia beetle new to Italy. Redia 81: 151–154.

Valkama H, Martikainen P, Raty M (1997) First record of North American ambrosia beetle *Gnathotrichus materiarius* (Fitch) (Coleoptera, scolytidae) in Finland - a new potential forest pest? Entomologica fennica 8: 193–195.

14.19 – *Phloeosinus rudis* Blandford, Japanese Thuja Bark Beetle (Coleoptera, Curculionidae, Scolytinae)

Leen Moraal

Description and biological cycle: Scolitid beetle, dark-brown, length of adults 2.5–3.0 mm (*Photo*). Females bore into the trunks of shrubs and trees weakened by drought and other stress factors. They excavate 2–3 armed egg galleries with a length varying from 5–16 cm. Feeding activity of the larvae kills the hosts. The diameter of emergence holes varies from 1.1–1.9 mm. The beetle overwinters, with a small percentage of adults, since the larval stage predominates. This weevil produces one generation per year. The photo shows an adult and also larval galleries in a 60-year-old tree of *Thuja occidentalis*. Host plants are *Thuja, Chamaecyparis* and *Juniperus.*

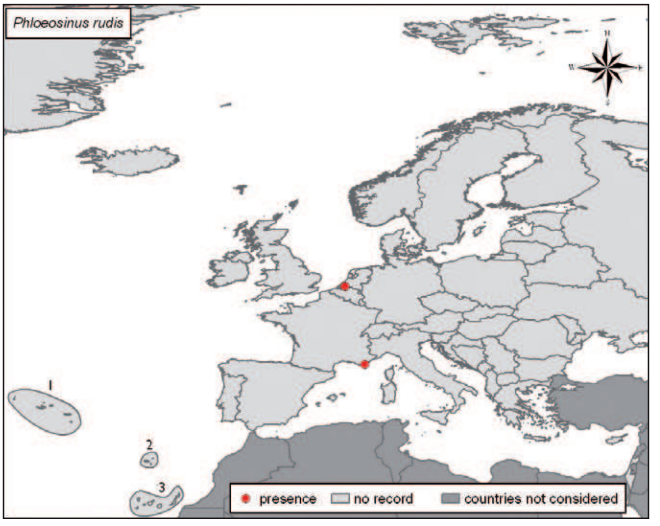
Native habitat (EUNIS code): G3- Coniferous forests.

Habitat occupied in invaded range (EUNIS code): X24- Domestic gardens of city and town centres; X25- Domestic gardens of villages and urban peripheries.

Native range: Japan

Introduced range: First found outside Japan in Southern France near St-Tropez, in June 1940, in dying branches of a *Thuja japonica* plantation. However, the beetle has not been

Credit: Leen Moraal



recorded in France since then. During the summer of 2004, hundreds of conifers, old solitary trees as well complete hedges, died in several cities around Rotterdam. Between 2004–2008, few infestations were found. This is probably due to the return to normal summer precipitation of the years following 2004, leading to more vigorous plants with less infestation. Because small beetle populations may survive in weakened trees, a new drought period may result in a new weevil population build-up.

Pathways: All Dutch locations were situated within 30 km of the harbour of Rotterdam. It is suspected that *P. rudis* may have escaped from imported material from this harbour, but this could not be verified. The beetle was intercepted several times in the USA in wood off-cuts integrated in steel products from Asia, but there are no records of establishment in the USA.

Impact and management: Symptoms become visible in summer when the needles turn brown and the hosts are dying. Removal and destruction of larval infested plants is recommended to control populations.

Selected references

Balachowsky A (1949) *Coléoptères scolytides*. Faune de France 50. Paris : Lechevallier, 124–126.

Hoffmann A (1942) Description d 'un genre nouveau et observations diverses sur plusieurs espèces de Scolytidae (Col.) de faune Francaise. Bulletin de la Société Entomologique de France 47: 72–74.

Pfeffer A (1995) Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypididae). Pro Entomologia, Naturhistorisches Museum, Basel: 69.

14.20 – *Xylosandrus crassiusculus* (Motschulsky, 1866) - Granulate Ambrosia Beetle (Coleoptera, Curculionidae, Scolytinae)

Massimo Faccoli

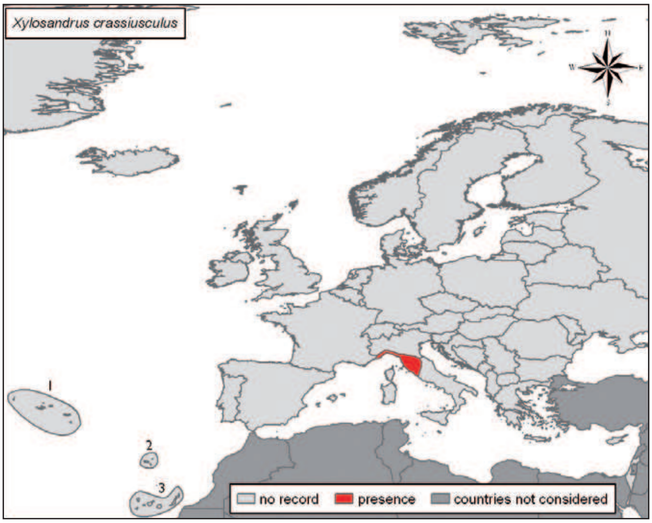
Description and biological cycle: The adult is about 2.1–2.9 mm long, with stout body, elytra 1.15 times longer than pronotum and reddish (*Photo left- female*). Elytra with vestiture of long setae in irregular rows. Elytral declivity dull, with dense, numerous, uniformly distributed granules, allowing easy distinction from other *Xylosandrus* species occurring in Europe. Male smaller than female, rare. *Xylosandrus crassiusculus* is an ambrosia beetle developing within the wood and feeding on the mycelium of ambrosia fungi. Mated females bore small chambers and lay eggs in groups. Larvae develop together feeding on the fungus growing on the chamber walls. During gallery formation, the female compacts and pushes out the frass, which extends from the entrance hole forming a long, easily visible cylinder (*Photo right*). The adults usually overwinter in galleries at the base of the trees. *X. crassiusculus* develops in Europe on Carob tree, *Ceratonia siliqua,* but is highly polyphagous in the native range on *Pinus* spp. and broadleaved trees.

Native habitat (EUNIS code): G - Woodland and forest habitats and other wooded land

Habitat occupied in invaded range (EUNIS code): G2 - Broadleaved evergreen woodland; J100- Greenhouses.

Native range: Paleotropical species (Africa and Asia)

Credit: meta.arsia.toscana.it (left), EPPO (right)



Introduced range: since 2003 recorded in Europe (Italy: Tuscany and Liguria- *Map*), probably introduced with infested trees or timber. Also introduced in North America.

Pathways: Long-distance dispersal is possible by trade of infested timber.

Impact and management: This beetle may disturb forest ecosystems by direct and indirect competition with native xylophagous insects. It may attack trees from about 2 cm stem diameter upwards in both stressed plants and is found in harvested timber. At high population density, *X. crassiusculus* may attack and kill healthy trees causing significant economic loss. Infested timber has reduced value because of adult galleries and black discolouration due to associated ambrosia fungi. Population monitoring and control may be performed using pheromone traps and the trees themselves as traps. Mechanical control is effected by destruction of infested trees via chipping or burning. Chemical control has limited effect because the insects develop deep within wood.

Prevention is achieved via timber debarking before insect infestation and by keeping trees in good physiological condition.

Selected references

Pennacchio F, Roversi PF, Francardi V, Gatti E (2003) *Xylosandrus crassiusculus* (Motschulsky) a bark beetle new to Europe. Redia 86: 77–80.

14.21 – *Xylosandrus germanus* (Blandford, 1894) (= *Xyleborus germanus*) - Black stem borer (Coleoptera, Curculionidae, Scolytinae)

Massimo Faccoli

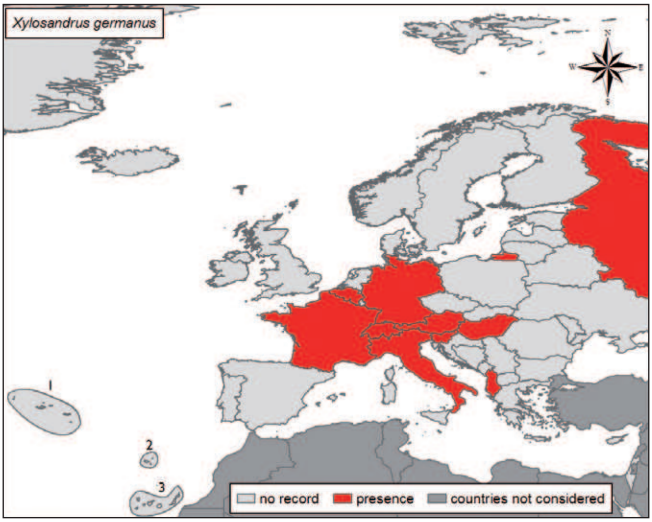
Description and biological cycle: Ambrosia beetle, 2.0–2.4 mm long, with shiny black elytra, surface of *elytral de*clivity* shining, anterior margin of pronotum with 8–10 *asperities** (*Photo*). This species is highly polyphagous on conifers and broadleaves, attacking a wide range of both living plants and timber. Adults fly during early to mid May, infesting timber of the lower part of the trunk of stressed trees. By specialized organs (*tegumental mycangia**), during tunnel excavation, the female introduces the pathogenic fungus *Ambrosiella hartigii* (Batra) (= *Monilia candida* Hartig) into the host plants. The associated fungus causes cankered areas in the stem and treetop as well as branch dieback and suckering. During gallery formation, frass ejected by the female often protrudes as a long and conspicuous cylinder. Although in Europe generally considered to be monovoltine, two generations per year have been observed in Germany and Italy. Adults of *X. germanus* usually overwinter in galleries at the base of attacked trees. Hosts in the invaded range include both broadleaved species (*Fagus, Castanea, Buxus, Ficus, Carpinus, Quercus* and *Juglans*) and conifers (*Picea* and *Pinus*).

Native habitat (EUNIS code): G - Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): G - Woodland and forest habitats and other wooded land.

Native range: Asia.

Credit: Christoph Benisch, kerbtier.de



Introduced range: First detected in Germany in 1950. Then, the weevil spread in most countries of Western and Central Europe as far as the European part of Russia (Map). Increasing frequency of interceptions has been reported during recent years in Europe. Also introduced in North America.

Pathways: Man-mediated long-distance dispersal is possible by movement of infested timber.

Impact and management: This weevil may disturb forest ecosystems by direct/indirect competition with native xylophagous insects. Such *secondary** species have been recorded on stressed living trees or harvested timber. Water stress is one of the main causes inducing stem colonization of living trees. Infestation kills the host plant and reduces timber value because of damage from adult galleries and black discolouration due to associated ambrosia fungi. Population monitoring and control may be performed by pheromone traps and trees used themselves as traps. Mechanical control involves destruction of infested trees by chipping or burning. Chemical control is of limited effect because the insects live deep within wood. Damage reduction and prevention may rely on timber debarking before insect infestation and keeping trees in good physiological condition.

Selected references

Bruge H (1995) *Xylosandrus germanus* (Blandford, 1894) [Belg. sp.nov.] (Coleoptera Scolytidae). Bulletin et annales de la Société Royale Belge d'Entomologie 131: 249–264.

Graf E, Manser P (1996) Der Schwarze Nutzholzborkenkäfer, *Xylosandrus germanus.* Wald und Holz 2: 24–27.

Henin JM, Versteirt V (2004) Abundance and distribution of *Xylosandrus germanus* (Blandford 1894) (Coleoptera, Scolytidae) in Belgium: new observations and an attempt to outline its range. Journal of Pest Science 77: 57–63.

14.22 – *Tribolium confusum* (Du Val, 1868) - Confused flour beetle (Coleoptera, Tenebrionidae)

Katalin Tuba and Ferenc Lakatos

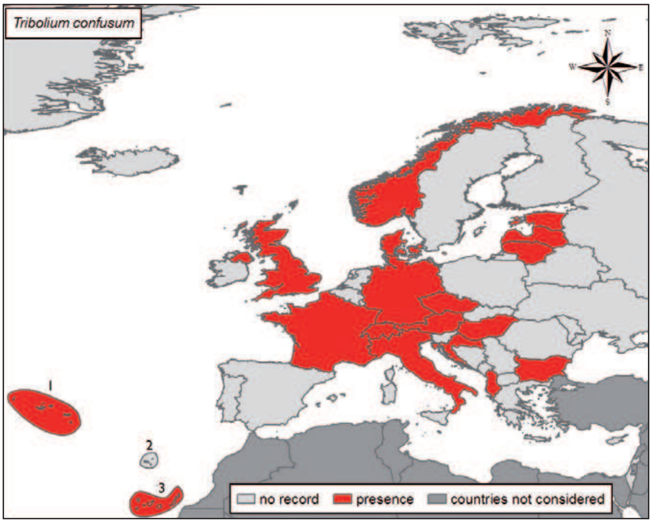
Description and biological cycle: Small beetle species. Adults are 2.6–4.4 mm long, shiny, reddish-brown or chestnut-brown (*Photo*). The first antennal segments are obscured by the forehead. Antennae widen from the 5–6th segment. The head and the pronotum are finely dotted. The elytra are patterned with lines also consisting of fine dots. Adults may live more than three years. Eggs are 0.4 mm long and white. Larvae have six larval stages. Their length is 6–7 mm in the final larval stage. Young larvae are white, aging yellowish. The body of larvae is cylindrical and slight hairy. On the ninth abdominal segment there are two hook-like projections. Larvae have three pairs of legs. The length of the yellowish brown pupa is 3–4 mm. There are three or five generations per year. Development time is about 40–45 days under optimal circumstances depending on sex, temperature, humidity and nutrition. Each female lays a total of 450–900 eggs. Females lay eggs one by one and thus the oviposition period is long. Eggs adhere well to the crop surface with a glue-like material. Larvae live for 3–4 weeks chewing crops. The pupa stage lasts a maximum of two weeks. The adults mature after 2–7 days. Adults overwinter in stores.

Native habitat (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats**;** J- Constructed, industrial and other artificial habitats.

Habitat occupied in invaded range (EUNIS code): J- Constructed, industrial and other artificial habitats.

Native range: Africa.

Credit: Christoph Benisch, kerbtier.de



Introduced range: All over the world. *Tribolium confusum* can withstand cooler climates than red flour beetle (*T. castaneum*), which is found in more temperate areas. The confused flour beetle moved into Europe from America at the end of the 19th century. Its range limit in Europe is now Scandinavia (*Map*).

Pathways: The wide geographical distribution of this pest is to a certain extent due to dissemination of infested stored products.

Impact and management: The confused flour beetle is one of the most important pests of the stored products in homes, groceries and granaries. This is a highly polyphagous species. Both adults and larvae cause damage, but the main pests are larvae. These attack flour, cereals, meal, crackers, pasta, cake, beans, peas, spices, dried pet food, chocolates, nuts, seeds and even dried museum specimens. Crops contaminated by larval skins, excrement and chewed residues are smelly and rendered inedible by both humans and animals. Physical and chemical as well as biological control can be used against this insect. Interestingly, cannibalistic interactions among certain life stages (eggs and pupae by adults, and eggs by larvae) constitute a natural control mechanism of confused flour beetles.

Selected references

Benoit HP, McCauley E, Post JR (1998) Testing the demographic consequences of cannibalism in *Tribolium confusum*. Ecology 79: 2839–2851.

Baldwin R, Fasulo TR (2003): *Tribolium confusum* Jacqulin du Val (Insecta: Coleoptera: Tenebrionidae). http://www.entnemdept.ufl.edu/creatures/urban/beetles/red_flour_beetle.htm [accessed 25 February 2010].

Jenser G, Mészáros Z, Sáringer Gy (Eds) (1998) A szántóföldi és a kertészeti növények kártevői. Mezőgazda Kiadó Budapest: 177–178.

14.23 – *Liriomyza huidobrensis* (Blanchard, 1926) - Serpentine leaf miner (Diptera, Agromyzidae)

Alain Roques

Description and biological cycle: Small fly, adult 1.3–2.3 mm long, compact-bodied, greyish-black (*Photo left*); maggot appears headless, up to 3.3 mm in length, yellow-orange at maturity. Larvae are leaf miners on a wide range of hosts, especially economically important vegetables and ornamental plants in both glasshouses and outdoors. Adult flight range is limited. Long-range dispersal (eggs, larvae) occurs with human-transported infested plant material, including cut flowers. The vase-life of chrysanthemums is sufficient to allow completion of the life-cycle. Under laboratory conditions, a female lays about 100–130 eggs but up to 250 eggs have been observed. Eggs are laid into the leaf tissue. Larvae tunnel within the leaf tissue forming characteristic mines (*Photo right- mines with a puparium*), then cut a semi-circular opening in the tissue and drop to the soil to pupate. The life cycle can be as short as 14 d at 30 °C or as long as 64 d at 14 °C. Generations follow in quick succession as long as the growing conditions of the host plant provide suitable food. Optimal temperatures for feeding and egg laying range between 21–32°C. Egg-laying is reduced at temperatures below 10 °C. All stages are killed within a few weeks by cold storage at 0 °C and above 40 °C.

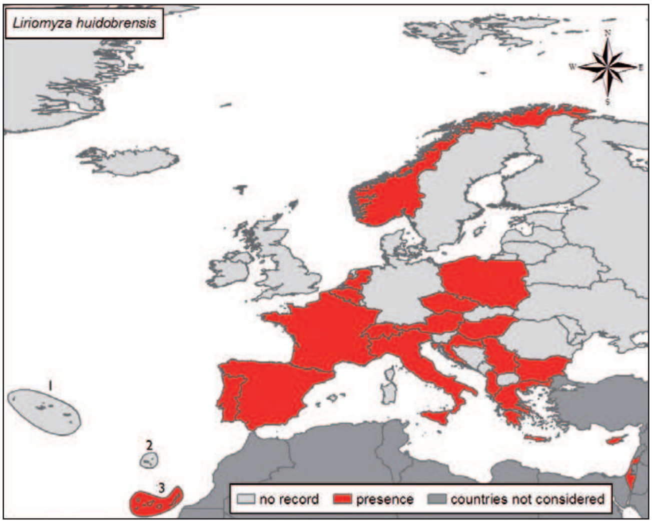
Native habitat (EUNIS code): F5- semi-arid and subtropical habitats

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; J100- glasshouses.

Native range: South America.

Introduced range: First recorded from France in 1989, spreading with imported ornamentals; now outdoors in southern Europe (including Sicily and the Canary islands- *Map*), but mainly a glasshouse pest in northern Europe. Also introduced in Central America, most of Asia (China, Taiwan, India, Thailand, Singapore, Indonesia), Asia Minor, Africa (Kenya), and Indian Ocean (Reunion, Mauritius, Seychelles).

Credit: Jean Yves Rasplus (left), Michel Martinez (right)



Pathways: Passive transport with plant trade including vegetables, cut flowers and nursery stock.

Impact and management: A serious pest for the floricultural industry, where leaf-miner damage directly affects the marketable portion, or in vegetable crops where the leaves are sold as the edible part. Sticky traps can be used to monitor adult flies. Crop rotation is an effective pest management tool, as is avoiding varieties more highly susceptible to leaf-miner infestations in glasshouses. There is little information about the leaf-miner tolerance of field vegetables. In this case, cultivation of crop debris or removal of infected plant material is recommended. *L. huidobrensis* adults are resistant to conventional insecticides. At present, the only effective insecticides are translaminar insecticides (abamectin, cyromazine, neem and spinosad), which penetrate the leaves to affect the leaf-miner larvae. Parasitoid wasps (e.g., *Diglyphus isaea* and *Dacnusa sibirica*)are available for control in glasshouse crops. These parasitoids will not be effective for vegetables growing in the field. However, there may be natural parasites present that can reduce the population.

Selected references

Maseti A, Luchetti A, Mantovani B, Burgio G (2006) Polymerase Chain Reaction-restriction fragment length polymorphism assays to distinguish *Liriomyza huidobrensis* (Diptera: Agromyzidae) from associated species lettuce cropping systems in Italy. Journal of Economic Entomology 99(4): 1268–1272.

Phalip M, Martinez M (1994) *Liriomyza huidobrensis* : ses plantes hôtes et les confusions possibles avec d' autres espèces. PHM Rev Hort 353: 24–28.

Scheffer SJ, Lewis ML (2001) Two nuclear genes confirm mitochondrial evidence of cryptic species within *Liriomyza huidobrensis* (Diptera: Agromyzidae). Annals of the Entomological Society of America 94: 648–653.

14.24 – *Liriomyza trifolii* (Burgess, 1880) - Chrysanthemum leaf miner (Diptera, Agromyzidae)

Ejup Çota

Description and biological cycle: The adult fly is small, greyish-black, compact-bodied, 1–1.3 mm in length, up to 1.7 mm in the female, with wings 1.3–1.7 mm (*Photo left*). Eggs are 0.2–0.3 mm x 0.10–0.15 mm, off-white and slightly translucent. The larva is a “headless” maggot up to 3 mm in length when fully grown. First instar larvae are colourless on hatching, turning pale yellow-orange. Later instars are yellow-orange. Female flies puncture the leaves of the host plants causing wounds, which serve as sites for feeding or oviposition. Eggs are inserted just below the leaf surface. Hatching occurs 2–5 days later and the three larval instars make serpentine mines in the leaves (*Photo right*). The larvae develop in a few days and leave the mine to pupate in the soil or in crop debris. There are many generations per year. The life cycle from oviposition to adult emergence can be as short as 12 d at 35°C or as long as 54 d at 15°C. Adult flies are capable of limited flight.

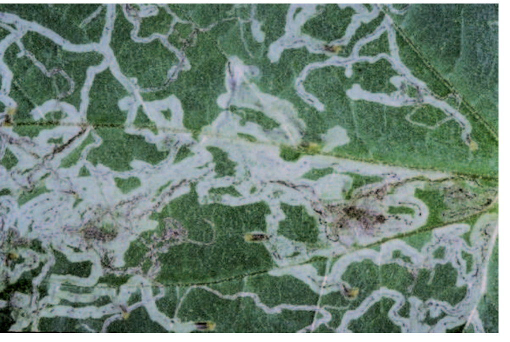
Native habitat (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; J100- glasshouses.

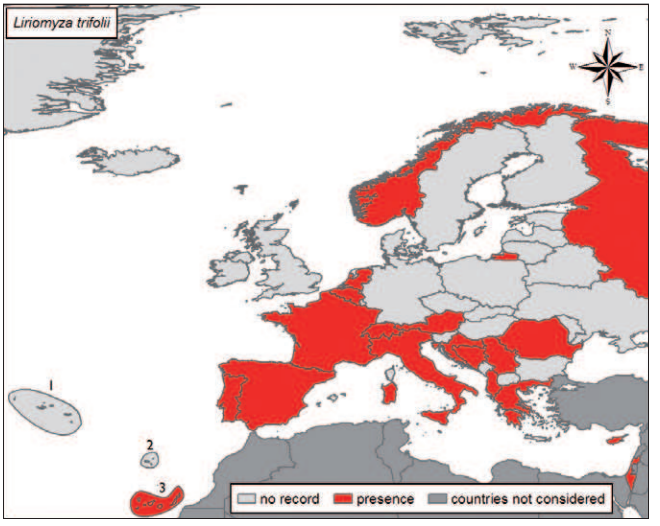
Native range: North America.

Introduced range: First detected in France in 1976, now occurring in most European countries (*Map*) but unable to overwinter outdoors in Northern and Central Europe, and found only in glasshouses in these regions.

Pathways: Trade of plant material, e.g. cut flowers, plants for planting out, and vegetables.



Credit: Rémy Coutin/ OPIE (left), Jean Pierre Lyon/ INRA (right)



Impact and management: Feeding and oviposition punctures of adults affect the value of ornamentals. However, damage is mainly done by larvae mining into the leaves and petioles, which reduces photosynthesis and may result in leaf drop. Mines are typically serpentine, tightly coiled and of irregular shape. *Liriomyza trifolii* is a major pest of various Asteraceae worldwide, both in outdoor crops and in glasshouses. It is particularly serious on Chrysanthemum, but also celery, onion, tomato, *Gerbera*, etc. In addition to the impact on yield, mines and feeding punctures also reduce the commercial value of ornamental plants and vegetables. Control by insecticides is feasible, although resistance is a problem. In glasshouses, the leaf miner is best controlled using natural enemies, such as parasitoids or nematodes. In field vegetables, cultivation of crop debris or removal of infected plant material is recommended. To prevent the introduction and establishment of *L. trifolii* and other leaf miner species, it is recommended that propagating material of susceptible plants from countries where the pests occur should be inspected at least every month for three months and verified free from the pests.

Selected references

Aguilar J d', Martínez M (1979) Sur la présence en France de *Liriomyza trifolii* Burgess. Bulletin de la Société Entomologique de France 84, 143–146.

Arzone A (1979) L'agromizide neartico *Liriomyza trifolii* (Burgess) nuovo nemico di Gerbera in Italia. Informatore Fitopatologico 29: 3–6.

Sher RB, Parrella MP (1996) Integrated biological control of leafminers, *Liriomyza trifolii*, on greenhouse chrysanthemums. Proceedings of the meeting Integrated control in glasshouses, held in Vienna, Austria, 20–25 May 1996. Bulletin OILB/SROP 1996: 147–150.

14.25 – *Dasineura gleditchiae* (Osten Sacken, 1866) - Honey locust pod midge (Diptera, Cecidomyiidae)

Ljubodrag Mihajlović and Milka M. Glavendekić

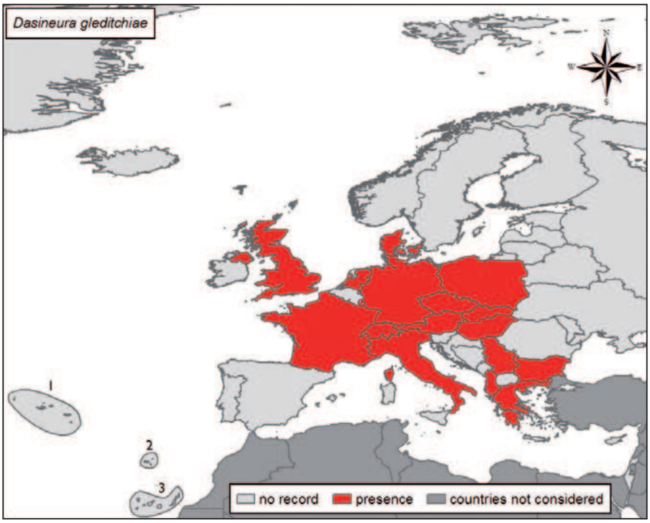
Description and biological cycle: Approximately 2.0–3.0 mm long, antennae, long, *moniliform** antennae with 12 flagellar segments, compound eyes *holoptic** with no ocelli. Thorax grey with two prominent black longitudinal stripes. First tarsomere considerably shorter than second segment out of five and tarsal claws with large, basal teeth. Mouthparts reduced. Unsculptured eggs elongate-ovoid and opaque-white, turning opaque-red. Larvae elongate and dorso-ventrally flattened with pebble-like integument, varying from white to orange. First-third larval instars 0.57–2.44 mm long. Pupae approximately 2.43 mm long, *obtect** with horn-like spines located at antennal base. Pupae sexually dimorphic; females with red and males with grey abdomen. *D. gleditchiae* is monophagous, living on *Gleditsia triacanthos* L. Generation time ranges from 21–30 days with several overlapping generations per year, overwintering as pupae or late instar larvae in cocoons in the soil. First appearance of the gall midge is in April, with males appearing first. Females deposit eggs on new foliage along the rachis or on edges of developing leaf buds. Eggs usualy hatch in two days. Young larvae crawl along the leaf to begin feeding. Only one larva is required to induce galling of the leaf. Leaf galls may be folded, partially pod-like, or the entire leaf may form a pod (*Photo*). The leaf gall dies and drops once the larvae pupate and emerge.

Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland; G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice.

Habitat occupied in invaded range (EUNIS code): FA- Hedgerows; I2 - Cultivated areas of gardens and parks and landscape; X24- Domestic gardens of city and town centres.

Native range: Nearctic species widespread in North America.

Credit: Milka M. Glavendekić



Introduced range: First discovered in Europe in 1980 in the Netherlands. Since that time, galls of this gall midge were recorded in several other countries of Central and Southern Europe (*Map*). Also introduced in Turkey.

Pathways: The main mode of introduction and spread is passive transport of coccons in soil with nursery stock or directly with infested young plants. Dispersal on a local scale is realized by active flight of adults and favoured by wind.

Impact and management: Honey locust pod gall midge is a major pest of honey locust. Feeding by midge larvae causes leaflets of new growth to form pod like galls in which the larvae pupate. After the adult midge emerges from the pod, the leaf tissue dies and drops prematurely. Much of new growth can be affected, reducing the aestetic quality of trees in nurseries and landscapes. Monitoring of honey locust trees in nursery and landscape sites should begin in early spring and throughout the growing season, noting the appearance of eggs deposited on buds and new foliage by overwintering and first generation adults. Clusters of red midge eggs on honey locust buds can be observed with a hand lens. Effective chemical control is achieved by using various organophosphates, pyrethroids, carbamates and neonicotinoids. Oil applications in a narrow date-range targeting the first two egg depositions in April should facilitate midge population suppression. Biological control can be achieved using the Nearctic parasitoid *Zatropis catalpae* Craw. (Hymenoptera., Pteromalidae).

Selected references

Bolchi Serini G, Volonté L (1985) *Dasineura gleditchiae* (Osten Sacken), Cecidomide nuovo per l´Italia (Diptera, Cecidomyiidae). Bollettino di Zoologia agraria e di Bachicoltura Ser. II 18: 185–189.

Dauphin P (1991) Sur la présence en France de *Dasineura gleditchiae* (Diptera, Cecidomyiidae), gallicole sur *Gleditsia triacanthos* (Fabacées, Caesalpinoidae). Bulletin de la Société Linnéenne de Bordeaux 19: 126.

Estal P, Soria S, Vinuela E (1998) Nota de la presencia en España de *Dasineura gleditchiae* (Osten Sacken), sobre acacia de tres espinas. Boletín de Sanidad Vegetal Plagas 24: 225–230.

14.26 – *Obolodiplosis robiniae* (Haldeman, 1847) - Black locust gall midge (Cecidomyiidae, Diptera)

Marcela Skuhravá

Description and biological cycle: Adult small, body 2.5–3.2 mm long, reddish-brown, with long antennae, hairy wings and long densely haired legs (*Photo left*). Larvae at first whitish, fully grown larvae pale yellow, with typical sclerotized organ - *spatula sternalis** – on ventral surface of prothoracic segments. Larvae are monophagous, inducing galls on leaves of black locust (*Robinia pseudoacacia*), a Fabaceae tree originating in North America. Larvae are gregarious and develop in galls formed of downwards rolled leaflet margins (*Photo right*). Several overlapping generations develop during one vegetative season. Pupation takes place in galls. In autumn, fully grown larvae leave galls and drop to the soil, where they hibernate till the spring of the next year. The population density is high.

Native habitat (EUNIS code): G1 - broadleaved and deciduous woodland, native in north-eastern part of USA.

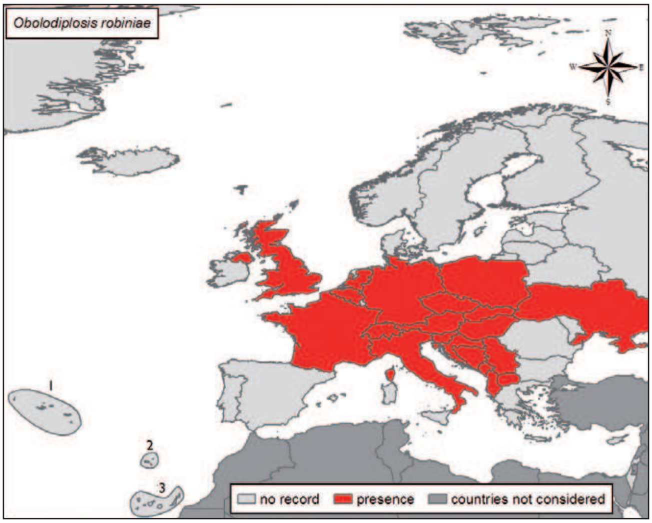
Habitat occupied in invaded range (EUNIS code): G5- Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I2 - Cultivated areas of gardens and parks; FB - Shrub plantations

Native range: North America.

Introduced range: Galls appeared suddendly in north-eastern Italy at Paese, Treviso Province in 2003, but the source of the infestation remains unknown. In 2004, the galls were found in northern Italy and in the Czech Republic at high infestation levels and in Slovenia. In the course of four years, the species spread very quickly in several countries of Europe and at present it occupies a large distribution area from England to Ukraine (Doneck) and from northern Germany to southern Italy (*Map*). The galls of *O. robiniae* appeared also suddendly in Korea and Japan in 2002. *O. robiniae* has a strong tendency to spread and can quickly become abundant in newly colonized areas.

Pathways: Black locust gall midge probably arrived in Europe with plant materials imported from the USA. The source of its rapid spread in Europe may be international traffic along

Credit: György Csóka (left), Vaclav Skuhravý (right)



roads. Larvae drop from the galls and may be transported in vehicles over large distances. Adult midges, due to their small size, may be transferred by the wind. Young seedlings in forest nurseries or nurseries raising ornamental shrubs and trees may be transported to new places hidden in their indistinct galls. High fecundity of females and exponential growth of populations in the course of one vegetative season has contributed to the rapid spread of this species in Europe.

Impact and management: Black locust is a tree with continual growth during the vegetative season. Nearly all leaflets of young shoots may be attacked by gall midges. Attacked leaflets dry up and fall off precociously after larval exit. The aesthetic value of damaged trees and shrubs is reduced. Monitoring may be achieved by visual detection of galls on trees and shrubs. Until now, insecticides have not been used to reduce populations. Natural enemies have been found in Europe, but surprisingly not in North America where *O. robiniae* is native. The endoparasitoid *Platygaster robiniae* (Hymenoptera: Proctotrupoidea: Platygastridae) has potential to reduce the gall midge population future biological control. The fungus *Beauveria bassiana* (Entomophthoraceae) was found during a study of gall midge larvae. Mechanical control is effected by cutting off infested parts with galls and burning is also recommended.

Selected references

Bathon H (2007) Die Robinien-Gallmücke *Obolodiplosis robiniae* (Haldeman) (Diptera: Cecidomyiidae) in Deutschland. Hessische Faunistische Briefe 26: 51–55.

Duso C, Fontana P, Tirello P (2005) Diffusione in Italia e in Europa di *Obolodiplosis robiniae* (Haldeman), dittero cecidomiide neartici dannoso a Robinia pseudoacacia. Informatore fitopatologico 5: 30–33.

Glavendekić M, Roques A, Mihajlović L (2009) An ALARM Case study: The Rapid Colonization of an Introduced Tree, Black Locust by an Invasive North-American Midge and Its Parasitoids. In: Settele J et al. (Eds) Atlas of Biodiversity Risks - from Europe to the globe, from stories to maps. Pensoft, Sofia & Moscow (www.pensoftonline.net/alarm-atlas-info, in press.

14.27 – *Aedes albopictus* (Skuse, 1894) - Asian tiger mosquito (Diptera, Culicidae)

Alain Roques

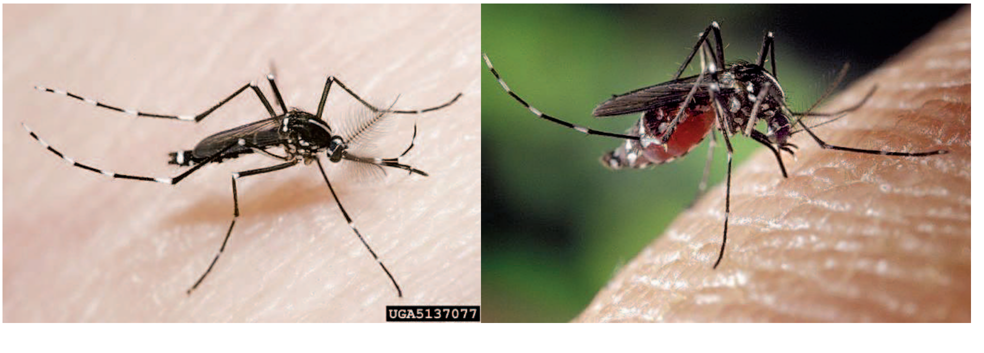
Description and biological cycle: Mosquito with black adult body and conspicuous white stripes on body and legs. Males (*Photo left*) have plumose antennae, whereas females have sparse short hairs (*Photo right- female on human skin*). Females are active during the day and are blood-feeders on vertebrates, including humans. Adult flight range is limited (200–400 m). Long-distance dispersal (eggs, larvae) mediated by human activity. Average fecundity of 150–250 eggs, up to 5 generations per year. Eggs are laid in the water in tree holes and domestic containers. Breeding populations are present from March to November; overwintering at egg stage. Eggs are resistant to desiccation and cold. Larvae require only 6 mm of water depth to complete life cycle. Areas at risk have mean winter temperatures higher than 0 °C, at least 500 mm precipitation and a warm-month mean temperature higher than 20 °C.

Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land; J6: Waste deposits. Typically breeds in tree holes and others small water collections surrounded by vegetation but also in peri-domestic containers filled with water.

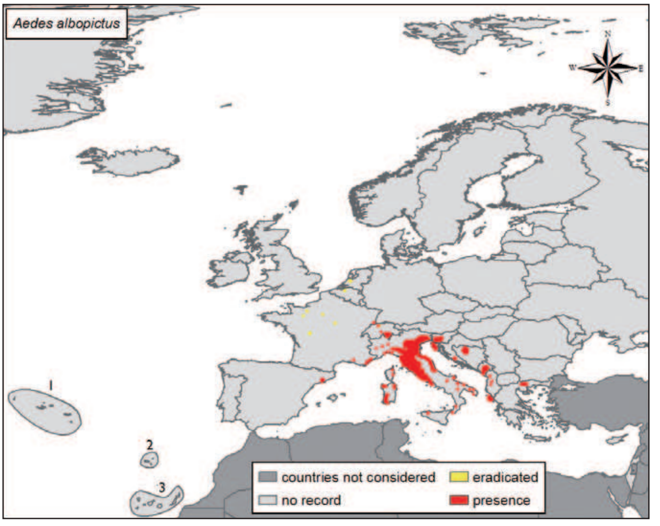
Habitat occupied in invaded range (EUNIS code): J6: Waste deposits. Mostly opportunistic container breeder capable of using any type of artificial water container, especially discarded tyres, but also saucers under flower pots, bird baths, tin cans and plastic buckets. It can establish in non-urbanised areas lacking artificial containers.

Native range: Southeast Asia.

Introduced range: Continuous spread all over the world since the late 1970s. First recorded in Europe in 1979 in Albania. Then, accelerated expansion was observed in Southern Europe since 2000, mostly along the Mediterranean Coast (*Map*). Some spots were detected in northwestern Europe, where it was tentatively eradicated. Also introduced in the Middle East, Africa, the Caribbean and North and South America.



Credit: Susan Ellis, Bugwood.org (left), James Gathany, Centres for Disease Control and Prevention, USA (right)



Pathways: Stowaway. Passive transport as dormant eggs via the international tire trade (due to the rainwater retained in the tires when stored outside), aircraft, boats and terrestrial vehicles and as larvae in "lucky bamboo" *Dracaena* spp., and other *phytotelmata** shipped with standing water.

Impact and management: Interspecific larval competition causes displacement of native mosquito species. Considerable health risk and economic costs result from the biting nuisance and the potential as vector for at least 22 arboviruses (including dengue, chikungunya, Ross River, West Nile virus, Japanese encephalitis, eastern equine encephalitis), avian plasmodia and dog heartworm filariasis *Dirofilaria*. For monitoring, ovitraps are used: artificial breeding containers (e.g., tyres) baited with frozen CO2 from dry ice. Mechanical control: removal of discarded tyres. All sources of standing water should be emptied every 3 d in areas at risk; water reserves that cannot be dumped can be treated with a spoonful of vegetable oil to suffocate mosquito larvae. To control larvae, spray water with derivates of *Bacillus thuringiensis israelensis* or larval growth inhibitors (diflubenzuron). To control adults, spray with deltamethrine. To control adults, spray with deltamethrine. Cyclopoid copepod predators (e.g., *Macrocyclops, Mesocyclops*) can be used for container-breeding larvae, and fishes and dragonflies in other situations.

Selected references

Eritja R, Escosa R, Lucientes J, Marquès E, Roiz D, Ruiz S (2005) Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. Biological Invasions 7: 87–97.

Gratz NG (2004) Critical review of the vector status of *Aedes albopictus*. Medical and Veterinary Entomology 18: 215–227.

Urbanelli S, Bellini R, Carrieri M, Sallicandro P, Celli G (2000) Population structure of *Aedes albopictus* (Skuse): the mosquito which is colonizing Mediterranean countries. Heredity 84: 331–337.

14.28 – *Ceratitis capitata* (Wiedemann, 1824) - Mediterranean fruit fly (Diptera, Tephritidae)

Alain Roques

Description and biological cycle: Small fly, 4–5 mm long. Adults with yellowish body, brown abdomen and legs, and yellow-banded wings (*Photo*). Larva 6–8 mm long at maturity, elongate, cream coloured, and of cylindrical maggot shape. Phytophagous on a wide range of temperate and subtropical fruits. Adult flight range up to 20 km but winds can carry flying adults over longer distances; intercontinental dispersal (eggs, larvae) via infested fruits transported by humans. Before reaching sexual maturation, adults feed 6–8 d on fruit juices. Females lay up to 22 eggs per day and 300–800 eggs during lifetime, under the skin of a fruit just beginning to ripen. Under tropical conditions, overall life cycle is completed in 21–30 d. Adults may survive for up to six months.

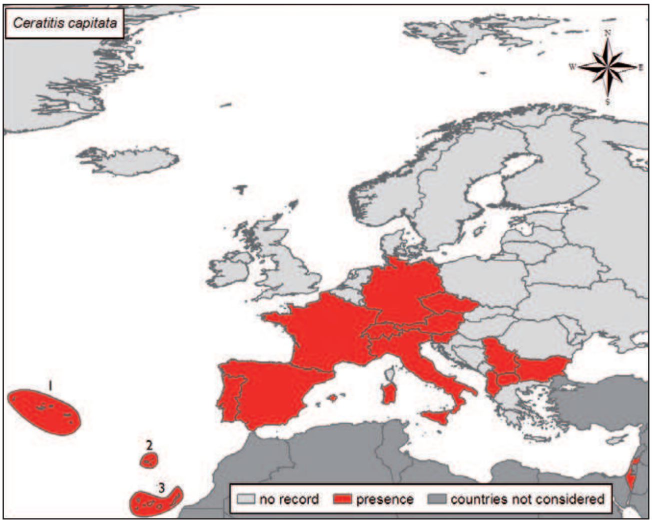
Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; I1- Arable land and market gardens.

Native range: Tropical Eastern Africa.

Introduced range: Observed in Europe since 1873 in Italy. Present all over southern Europe (*Map*); regularly observed but not established in other parts of Europe; global warming may allow populations to establish at higher latitudes than at present. It has also been introduced in Africa, Middle East, Central and South America, the Caribbean, Hawaii, Australia. Eradicated in USA except Hawaii.

Credit: Michel Martinez/ INRA



Pathways: Imported with fruit trade but also with passengers transporting infested fruits during trips.

Impact and management: Probably the most important fruit fly pest, inducing large damage in fruit crops, especially citrus fruits and peach. Fly damage results from both oviposition in fruit, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms (bacteria, fungi) that cause fruit rot. Their presence often requires host crops to undergo quarantine treatments, other disinfestation procedures or certification of fly-free areas. The costs of such activities and phytosanitary regulatory compliance can be significant and definitely affect global trade. To ensure early detection, traps baited with chemical attractants (especially trimedlure) can be used. Larvae can be killed by soaking, freezing, cooking or pureeing infested fruits. Fruits can be bagged to prevent egg laying. Field sanitation needs to destroy all unmarketable and infested fruits; harvesting fruit weekly also reduces food sources by keeping the quantity of ripe fruit on the trees to a minimum. Chemical sprays are not completely effective. It is better to use foliage baits combining a source of protein with an insecticide to attract both males and females. Biological control involves use of sterile insects and release of parasitoids.

Selected references

Copeland RS, Wharton RA, Luke Q, De Meyer M (2002) Indigenous Hosts of Ceratitis capitata (Diptera: Tephritidae) in Kenya. Annals of the Entomological Society of America 95: 672–694.

Liebhold AM, Work TT, McCullough DG, Cavey JF (2006) Airline Baggage as a Pathway for Alien Insect Species Invading the United States. American Entomologist 52: 48–56.

Malacrida AR, Marinoni F, Torti C, et al (1998) Genetic aspects of the worldwide colonization process of Ceratitis capitata. Heredity 89: 501–507.

14.29 – *Rhagoletis completa* Cresson, 1929 - Walnut husk fly (Diptera: Tephritidae)

Marc Kenis

Description and biological cycle: Adults are typical tephritid yellow-orange flies with black stripes on wings, 4–8 mm long (*Photo left*). Adults fly in summer, and can live up to 40 days. Breeds in the husks of walnuts (*Juglans* spp.). Eggs are laid under the skin of the host fruit and hatch after 3–7 days. Larvae feed for 2–5 weeks, usually in the mesocarp (*Photo right- larva emerged from a walnut*). Overwinters in its puparium in the soil. There is only one generation per year.

Native habitat (EUNIS code): G1 - Broadleaved deciduous woodlands; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

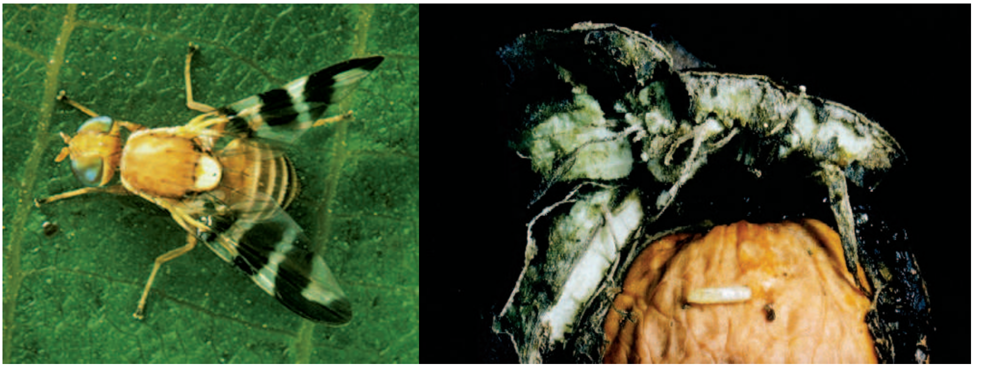
Habitat occupied in invaded range (EUNIS code): G1 Broadleaved deciduous woodland; I1- Arable land and market gardens. I2- Cultivated areas of gardens and parks.

Native range: North America.

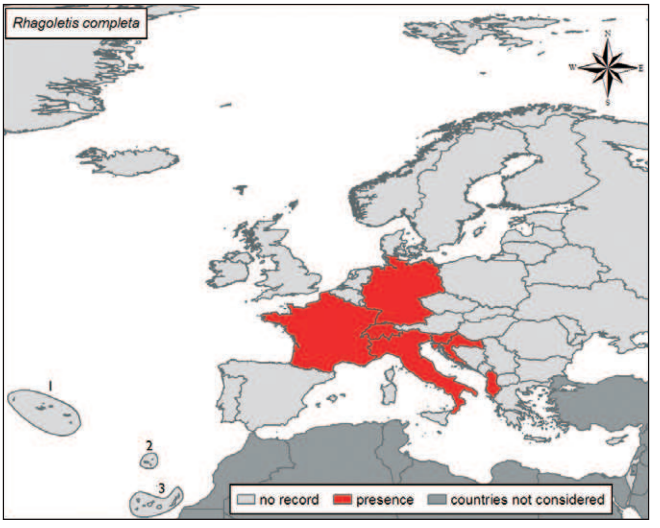
Introduced range: First found in Switzerland and Italy in the 1980s, from where it spread to several European countries, including France, Germany, Slovenia and Croatia (*Map*). Its distribution is closely linked to that of walnut species.

Pathways: The main mode of dispersal is probably human-mediated transport through larval infested fruits. Adults can fly, but only a short distance.

Impact and management: Attacked walnut fruits are pitted by oviposition punctures around which discolouration usually occurs. Larvae usually feed on the mesocarp, but



Credit: Erwin Mani, eppo.org



at high density, larvae also damage the pericarp and the nut itself. Walnuts attacked by the fly become unfit for sale, because of the discolouration of the nut. Walnut husk fly is a major pest of walnut in the USA. Since its introduction into Europe, populations are increasing, and severe damage has been observed, with up to 100% of harvested walnuts infested in some orchards. Various chemical treatments are effective against *R. completa*. Attacked fruits should be removed and destroyed before the larva emerges. Covering the soil under trees may prevent the larvae from entering the soil and pupating. Yellow sticky traps baited with ammonia can be used as a monitoring method, but are not efficient as a control method.

Selected references

Duso C, Lago G dal (2006) Life cycle, phenology and economic importance of the walnut husk fly *Rhagoletis completa* Cresson (Diptera: Tephritidae) in northern Italy. Annales de la Société Entomologique de France 42: 245–254.

Mani E, Merz B, Brunetti R, Schaub L, Jermini M, Schwaller F (1994) Zum Auftreten der beiden amerikanischen Fruchtfliegenarten *Rhagoletis completa* Cresson und *Rhagoletis indifferens* Curran in der Schweiz (Diptera: Tephritidae). Mitteilungen der Schweizerischen Entomologischen Gesellschaft 67: 177–182.

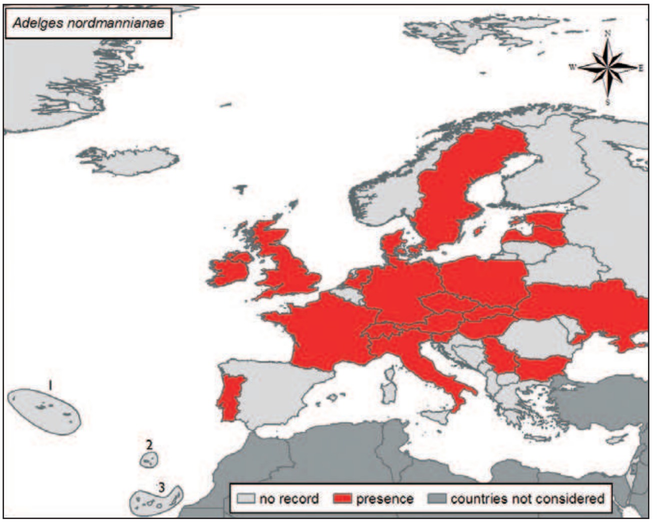
Romani M (1998) Gravi attacchi di *Rhagoletis completa* nei noceti lombardi. Informatore Fitopatologico 48: 13–16.

14.30 – *Adelges nordmannianae* (Eckstein, 1890) (= *Dreyfusia nordmannianae,* = *D. nüsslini* Börner) - Silver fir woolly aphid (Hemiptera, Adelgidae)

Hans Peter Ravn

Description and biological cycle: Winged female adult aphids (emigrants) from the primary host have a body length of 1.1–2.3 mm and wing span of about 4,6 mm. They are greenish just after the moult, turning darker. Winged female adults from the secondary host (remigrants) are grey-green and have a body length of 0.8–1.2 mm. Body length of parthenogenetic females is 0.7–1.5 mm; they are black-brown or black-violet. The body is covered with wax-wool. The small, turtle-shaped nymphs usually have only a peripheral fringe of wax round their body. In the native range, the aphid has a two-year life cycle with sexual reproduction on a primary host, Oriental Spruce, *Picea orientalis* (or *P. omorica*), and a parthenogenetic reproduction on a secondary host, Caucasian fir, *Abies nordmanniana,* which is replaced by European silver fir, *Abies alba,* in the introduced range in Europe. On *Picea orientalis*, aphids induce a 6- 8 mm gall (*Photo left*) growing from the short side-branches and also consisting of thickened needles. Galls are not induced on Abies species. The overwintering stage on the secondary host is 2nd-3rd instar larvae, situated on the shoot axis of the previous year's shoot. In early spring, they develop into egg-producing females. Each female produces 110–500 eggs in a rosette-shaped heap. After hatching, young larvae will move to the new shoots and suck either on the new shoot axis or on the needles (*Photo right*). Some of the larvae develop into winged adults that will try to re-migrate to *P. orientalis*. Needle-feeding larvae and some shoot feeding larvae develop into females producing 10–30 eggs, from which the larvae move to the shoot axis for overwintering.

Credit: L. Goudzwaard



Native habitat (EUNIS code): G3 - Coniferous woodland.

Habitat occupied in invaded range (EUNIS code): G3 - Coniferous woodland; I2 - Cultivated areas of gardens and parks; X24 - Domestic gardens of city and town centres; i.e. Christmas tree plantations (*A. nordmannianae*) in forests and on arable field land.

Native range: Mountain areas of Caucasus, Northeastern Turkey (Pontus) and Crimea.

Introduced range: First detected in 1840 in Germany, then spreading to stands of native *Abies alba* throughout the distribution range of this tree species in Europe (*Map*). However native Norway spruce, *Picea abies,* has not been accepted as a primary host. Therefore, the sexual life cycle rarely occurs in Europe.

Pathways: Forestry plantations of exotic conifers and trade of ornamental trees.

Impact and management: Aphid suction curls needles on new twigs. At severe attack levels, honeydew production may cause formation of sooty mould, loss of needles and even death of the leading shoot. Attacks are more abundant and severe in the region of introduction than in the region of origin. Silver fir woolly aphid has developed into the severest pest problem for Christmas tree production in Europe. Silver fir woolly aphid is responsible for the major part of insecticides used in Christmas trees.

Selected references

Eichhorn O (1991) On the generation cycle of *Dreyfusia nordmannianae* Eckst. (Hom., Adelgidae). Journal of Applied Entomology 112: 217–219.

Schneider-Orelli O, Schaeferrer C, Wiesmann R (1929) Untersuchungen über die Weisstannenlaus *Dreyfusia nüsslini* C.B. in der Schweiz. Mitteilungen der schweizerischen Cebtralanstalt für das forstliche Versuchswesen 15: 191–242.

Varty IW (1956) Adelges Insects of Silver Firs. Edinburgh: Her Majesty's Stationery Office. 75 pp.

14.31 – *Bemisia tabaci* (Gennadius, 1889) - Cotton whitefly (Hemiptera, Aleyrodidae)

Alain Roques

Description and biological cycle: Small, about 1 mm long, sap-sucking whitefly with two pairs of white wings and a white to light yellow body, covered with waxy powdery material (*Photo left*). Larvae also sap-sucking, feeding on > 900 plant species. This taxon corresponds to a species complex that comprises a large number of genetically variable populations, some of which are discernible owing to distinct phenotypes. Well-studied *B.tabaci* populations that have been differentiated are referred to as races or biotypes. The B biotype is a particularly aggressive variant. One female produces 80–300 eggs per lifetime. Unmated females produce parthenogenetically only male progeny. Development needs 15–70 d from egg to adult depending on temperature (10–32 °C, 27 °C is optimal), while 11–15 generations per year are possible (*Photo right- empty exuviae*).

Native habitat (EUNIS code): Unknown.

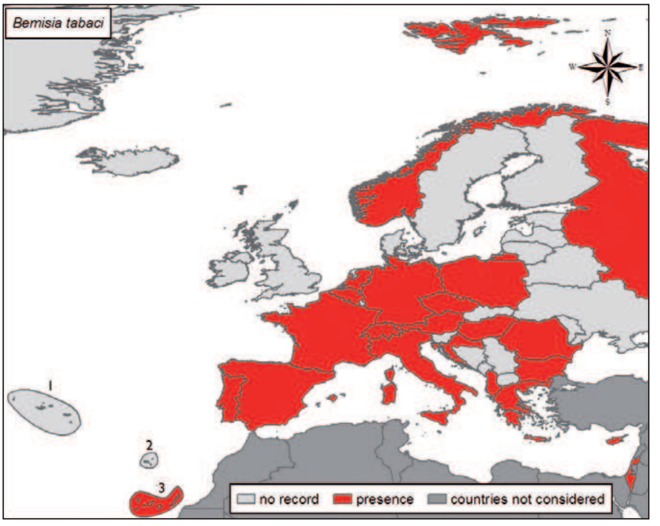
Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; I1- Arable land and market gardens; glasshouses.

Native range: Asia -Pacific region. Cotton whitefly appears to be a species complex. Recent genetic data indicate as many as ten morphologically indistinguishable species indigenous to the Asia-Pacific region.

Introduced range: Widely spread in the last 15 years. Reported at present from all continents; present in the field in most of Southern Europe but restricted to glasshouses in Western, Central and Northern Europe (*Map*). Apparently eradicated in Finland, Ireland and the United Kingdom.

Pathways : Intercontinental dispersal of eggs, nymphs and adults occurs with plant trade. Directional adult flight is limited but winds may carry flying adults over long distances due to their small size.

Credit: Jean Yves Rasplus (left), Jean Claude Streito (right)



Impact and management: Heavy infestations cause important yield losses, ranging from 20–100% depending on the crop and season, to both field and glasshouse agricultural crops and ornamental plants. Three types of damage are observed. Direct feeding damage by adults and larvae may reduce host vigour and growth, cause chlorosis and uneven ripening, and induce physiological disorders. Indirect damage results from accumulation of honeydew produced by nymphs, which serves as a substrate for the growth of black sooty mould on leaves and fruit. The mould reduces photosynthesis and lessens market value of the plant or yields it unmarketable. Finally, it is the most important vector of plant viruses worldwide. As vector of over 100 plant viruses, a small population of whiteflies is sufficient to cause considerable damage. Avoid importations from infested areas. Sequential plantings, avoiding the establishment of affected crops near infested fields, can be used. Adult activity and abundance can be monitored using yellow sticky traps. Chemical control: a number of insecticides provided effective control in the past, but resistance has developed rapidly. Biological control: the use of natural enemies such as chalcids (e.g., *Encarsia formosa, Eretmocerus* spp.) and the entomopathogenic fungus *Verticillium lecanii* is moderately efficient, but cannot sufficiently decrease infestations to stop virus transmission.

Selected references

De Barro PJ (2005) Genetic structure of the whitefly *Bemisia tabaci* in the Asia-Pacific region revealed using microsatellite markers. Molecular Ecology 14: 3695–3718.

Martin JH, Rapisarda C, Mifsud D (2000) The whiteflies (Hemiptera: Aleyrodidae) of Europe and the Mediterranean Basin. Bulletin of Entomological Research 90: 407–448.

Moya A, Guirao P, Cifuentes D, Beitia F and Cenis JL (2001) Genetic diversity Genetic diversity of Iberian populations of *Bemisia tabaci* (Hemiptera: Aleyrodidae) based on random amplified polymorphic DNA-polymerase chain reaction. Molecular Ecology 10: 891–897.

14.32 – *Trialeurodes vaporariorum* (Westwood, 1856) - Glasshouse whitefly (Hemiptera, Aleyrodidae)

Alain Roques

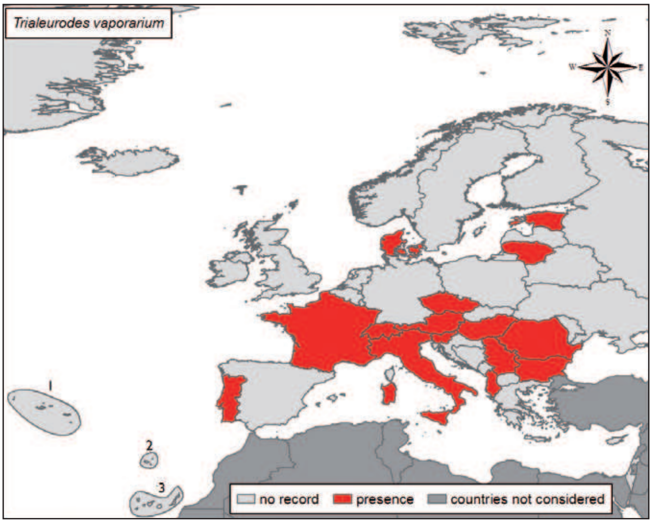
Description and biological cycle: Adult small, white to pale yellow, about 1mm long; the wings held relatively flat when at rest and coated with powdery wax (*Photo- adult male*). While single whitefly can be difficult to see, large numbers clustered on the underside of leaves are very obvious. They tend to fly rapidly when the plant is disturbed. The female may lay more than 500 eggs during its 3–6 weeks- long life. Eggs are laid in a circle on smooth leaves; on hairy leaves, they are more dispersed and less regularly situated. The eggs hatch about 9 days after egg-laying at 21°C. Newly emerged nymphs are mobile for a short period before settling to feed, their stylets inserted in leaf tissue, passing through three instars. Then, they stop feeding, moult and remain in a pupa for about 18 days. Reproduction is essentially parthenogenetic. Overwintering occurs at all instars. In northern climates, this whitefly usually lives in glasshouses on wild plants, or in summer on adjacent plants outside. Further south, adults may also overwinter on wild plants growing outdoors if the climatic conditions are not too severe. Reproduction occurs throughout the year when conditions are favourable, with several generations overlapping. Under optimum conditions at 21–24°C, the development from egg to adult takes about 3–4 weeks. Highly polyphagous, this species is capable of attacking 249 genera of plants. It attacks mainly vegetables, especially tomatoes, cucumbers and several other economic plants especially when they are grown in greenhouses. It can also be found on a wide selection of ornamentals, with a prediliction for *Asteraceae,* and of weeds, including sow thistles (*Sonchus* spp.), milkweed (*Euphorbia peplus*), and mallows (*Malva* spp.).

Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): J100- glasshouses; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; I1- Arable land and market gardens.

Native range: Central America, essentially tropical and subtropical.

Credit: LNPV/ Montpellier Station



Introduced range: First recorded in Europe in Great Britain in 1856. Nowadays, present in the major part of Western, Central and Southern Europe (*Map*). In cold regions, this whitefly is found only in heated glasshouses whilst it may occur outdoors in southern Europe on both wild and cultivated plants.

Pathways: Intercontinental dispersal of eggs, nymphs and adults occurs with plant trade. Directional adult flight is limited but winds may carry flying adults over long distances due to their small size.

Impact and management: A major pest in glasshouses. The whitefly is responsible for very severe damage on vegetables through both sap sucking, and the production of honeydew and the consequent formation of sooty moulds. Up to 2,000 nymphs may be found on a single bean leaf, each being capable of producing 20 drops of honeydew in an hour. Affected tomatoes cannot be sold. The species may also transmit viruses.A certain resistence to synthetic insecticides has been observed, particularly amongst parthenogenetic strains. Populations are controlled by the action of entomophagous species such as fungi, ladybirds, Neuropterae, and hymenopteran chalcids. Biological control is widely used in commercial glasshouses, by introduction of a small endoparasitic wasp, *Encarsia Formosa* Gahan, which attacks and kills the whiteflies. Other biological control agents becoming available to gardeners include a small black ladybird, *Delphastus* sp., and a small predatory bug, *Macrolophus* sp.

Selected references

Kirk AA, Lacey LA, Roditakis, N Brown JK (1993) The status of *Bemisia tabaci* (Hom.: Aleyrodidae), *Trialeurodes vaporariorum* (Hom.: Aleyrodidae) and their natural enemies in Crete. Entomophaga 38: 405–410.

Martin JH, Rapisarda C, Mifsud D (2000) The whiteflies (Hemiptera: Aleyrodidae) of Europe and the Mediterranean Basin. Bulletin of Entomological Research 90: 407–448.

Van Dorst HJM, Huijberts N, Bos L (1983) Yellows of glasshouse vegetables, transmitted by Trialeurodes vaporariorum. European Journal of Plant Pathology 89: 171–184.

14.33 – *Aphis gossypii* Glover, 1877 - Cotton aphid, melon aphid (Hemiptera, Aphididae)

Alain Roques

Description and biological cycle: Small aphid, about 2 mm long, phloem-feeding with two virginiparous forms. Winged and wingless, highly variable in colour from yellowish green to partly black; immature stages pale yellow to pale green (*Photo- wingless female and immatures*). Highly polyphagous species, a major pest of cultivated plants in the families Cucurbitaceae, Rutaceae, Malvaceae and of Citrus trees. Flight range of winged adults is limited. Long-range dispersal of eggs, immature stages and adults is human-mediated with the transport of infested plant material. In Europe, it reproduces by apomictic parthenogenesis, and can produce nearly sixty generations a year. The optimal temperature is 21–27 °C. Viviparous females produce 70–80 offspring at a rate of 4.3 per day. Developmental periods of immature stages vary from 21 d at 10°C to 4 d at 30°C. Good resistance to summer heat. Dry weather conditions are favourable and heavy rainfall decreases population sizes.

Native habitat (EUNIS code): Unknown.

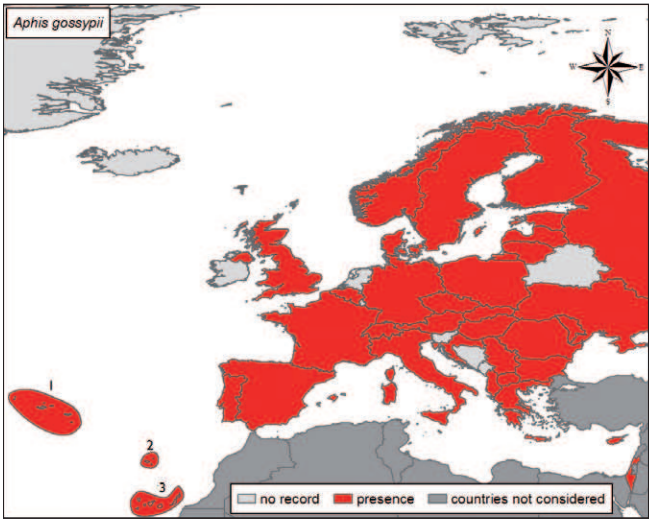
Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; J100- glasshouses.

Native range: Unknown.

Introduced range: Found in tropical and temperate regions throughout the world except northern areas. Common in Africa, Australia, Brazil, East Indies, Mexico and Hawaii, Present in most of Europe (*Map*) but it can develop outdoors only in Southern Europe, surviving in glasshouses in Northern Europe.

Pathways: Passive transport with plant trade including vegetables, fruits, cut flowers, ornamental plants, bonsai, and nursery stock.

Credit: Jérôme Carletto



Impact and management: Economically important because nymphs and adults feed on the underside of leaves, or on growing tip of vines, sucking nutrients from the plant. The foliage may become chlorotic and die prematurely. Feeding also causes distortion and leaf curling, hindering photosynthetic capacity of the plant. In addition, honeydew production fosters growth of sooty moulds, resulting in a decrease of fruit/vegetable quantity and quality. Vector of crinkle, mosaic, rosette, Tristeza citrus fruit (CTV) and other virus diseases. Impact is especially high on courgette, melon, cucumber, aubergine, strawberry, cotton, mallow and citrus. Resistance has arisen to many pesticides. Insecticides should be used sparingly and in conjunction with other non-chemical control methods. Parasitoid aphidiid wasps (e.g., *Aphidius colemanior, Lysiphlebus testaceipes*), aphelinid wasps (e.g., *Aphelinus gossypii*), predatory midges (e.g., *Aphidoletes aphidimyza*), predatory anthocorid bugs (e.g., *Anthocoris* spp.), predatory coccinelids, and entomopathogenic fungi (e.g., *Neozygites fresenii*) are efficient and available for biocontrol in glasshouse crops.

Selected references

Fuller SJ, Chavigny P, Lapchin L, Vanlerberghe-Masutti F (1999) Variation in clonal diversity in glasshouse infestations of the aphid, *Aphis gossypii* Glover in southern France. Molecular Ecology 8: 1867–77.

Margaritopoulos JT, Tzortzi M, Zarpas KD, Tsitsipis JA, Blackman RL (2006) Morphological discrimination of *Aphis gossypii* (Hemiptera: Aphididae) populations feeding on Compositae. Bulletin of Entomological Research 96: 153–165.

Martin B, Rahbé Y, Fereres A (2003) Blockage of stylet tips as the mechanism of resistance to virus transmission by *Aphis gossypii* in melon lines bearing the Vat gene. Annals of Applied Biology 142: 245–250.

14.34 – *Cinara curvipes* (Patch, 1912) - Bow-legged fir aphid (Hemiptera, Aphididae)

Olivera Petrović-Obradović

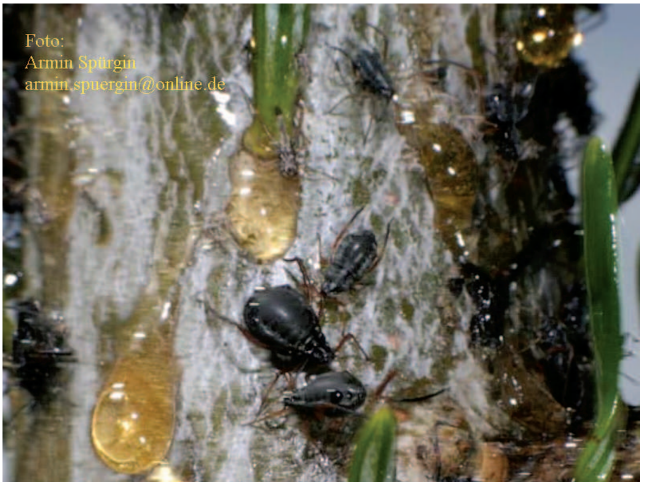
Description and biological cycle: Wingless viviparous females are pearlike, 4–6 mm long. Body is dark brown, almost black, glossy, with two long white wax lines, extending dorsally from head to end of abdomen (*Photo*). Cornicles are short, on an oval sclerotised plate. Cauda are short and rounded. Rostrum is very long and may exceed the length of the body. Winged viviparous females are somewhat finer, with well developed wings. Monoecious species (host alternation does not occur) on *Abies* spp., *Cedrus athlantica* and *Cedrus deodora*. In America, develops a sexual generation in autumn, but in Europe, males have not been observed and it seems that it has *anholocyclic** development.

Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

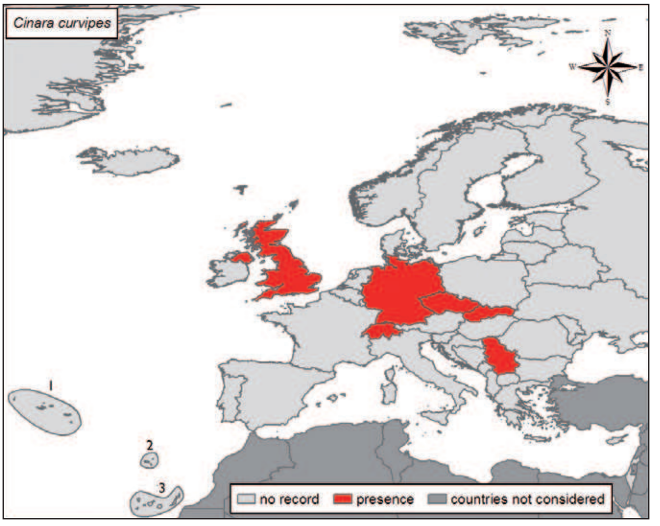
Habitat occupied in invaded range (EUNIS code): G3- Coniferous woodland; G3F- Highly artificial coniferous woodland; G5- Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland; I2- Cultivated areas of gardens and parks; X24- Domestic gardens of city and town centres; X25- Domestic gardens of villages and urban peripheries.

Native range: North America and Mexico

Introduced range: First recorded in Germany in 2000, later found in Serbia (2001), Switzerland (2007), Slovakia (2007) and Czech Republic (2008).



Credit: Armin Spürgin



Pathways: Introduced with infested coniferous host plants. Spread in Europe continues by transport of the host plants and by active and passive flight of winged viviparous females.

Impact and management: Economically one of the most important aphids as it is a pest of many crops (peach, potato, tobacco, sugar beet, vegetables, ornamental plants). Also, among aphids, it is the most efficient vector of plant viruses, transmitting more than 100 nonpersistent and many important persistent viruses, including Potato leaf roll (PLRV), Bean leaf roll (BLRV), Pea enation mosaic (PEMV) and Beet yellow net (BYNV). For monitoring flight activity, yellow water traps and suction traps are used. For chemical control, since resistance to insecticide is easily developed, only a few new insecticides are sufficiently effective. Many predators act as biological controls in colonies of the pest, especialy Coccinelidae, Syrphidae, Chrysopidae, Miridae and Cecidomyiidae (*Aphidoletes aphidomyza* Rond.). A very rich parasitoid complex includes 18 species of Aphidiidae wasp. Two of them are used in control in glasshouses: *Aphididus colemani* Vier. and *Aphidius ervi* Hal.

Selected references

Balachowsky A, Mesnil L (1935) Les insectes nuisibles aux plantes cultivées. Paris, France: Mery L. 1921 pp.

Blackman RL, Eastop VF (2000) Aphids on the World's Crops - an Identification and Information Guide. 2nd edn. Chichester UK: John Wiley & Sons. 476 pp.

Theobald FV (1926)The plant lice or *Aphididae* of Great Britain, Vol I., London, UK: Headley Brothers. 372pp.

14.35 – *Macrosiphum euphorbiae* (Thomas, 1878) - Potato aphid (Hemiptera, Aphididae)

Olivera Petrović-Obradović

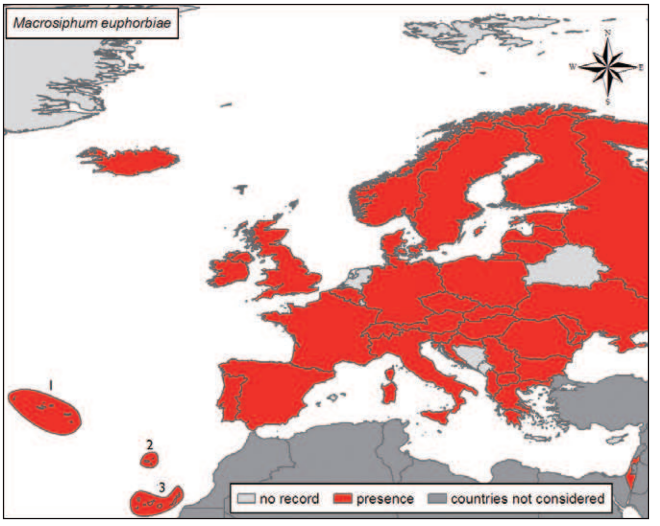
Description and biological cycle: Medium-sized to large aphid (1.7–3.5 mm), spindle-shaped, green (*Photo*) or pink. Adults are rather shiny and larvae have a light dusting of greyish-white wax. Mainly *anholocyclic**, usually with only winged and wingless forms present in colonies. Sexual morphs are produced on primary host (*Rosa* spp.) in North America and only rarely in other parts of the world. Highly polyphagous on secondary hosts, feeding on plant species in more than 20 different plant families. In Europe, develops usually without sexual generation. During winter, regularly found in glasshouses.

Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): : I1 - Arable land and market gardens; I2- Cultivated areas of gardens and parks; glasshouses; X7 - Intensively-farmed crops interspersed with strips of spontaneous vegetation. X24 - Domestic gardens of city and town centres; X25: Domestic gardens of villages and urban peripheries.

Native range: North America.

Credit: Rémi Coutin/ OPIE



Introduced range: Cosmopolitan species. In Europe, first found in 1917 in Great Britain. Then, the potato aphid colonized most of Europe (*Map*).

Pathways: Trade of ornamentals.

Impact and management: Serious pest of many crops (potato, vegetable, flowers), causing direct damage by sucking nutrients and indirect damage as a vector of viruses. This aphid can transmit more than 40 non-persistent viruses and five persistent viruses (potato leaf roll, beet yellow net, bean leaf roll, zucchini yellow mosaic and sweet potato leaf-speckling virus). Monitoring can be effected using yellow water traps and suction traps. Chemical control involves use of selective insecticide and is often both necessary and effective. Many specific predators and parasitoids can be used for biological control, epecially in glasshouses.

Selected references

Blackman RL, Eastop VF (2000) Aphids on the World's Crops - an Identification and Information Guide. 2nd edn. Chichester UK: John Wiley & Sons. 476 pp.

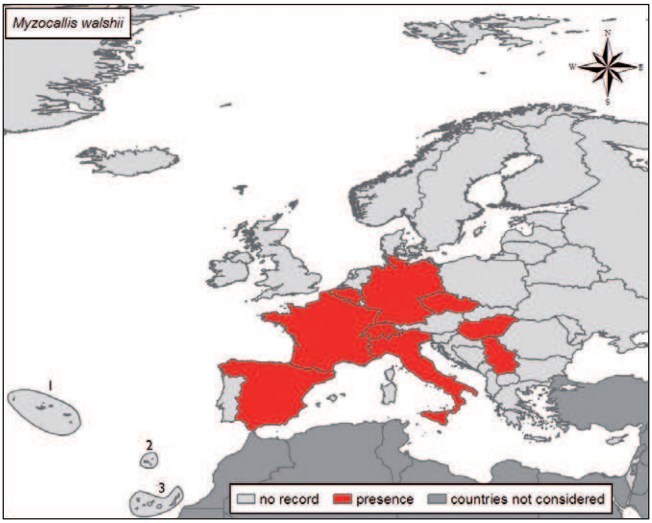
Eastop VF (1958) The history of *Macrosiphum euphorbiae* (Thomas) in Europe. The Entomologist 91: 198–201.

14.36 – *Myzocallis walshii* (Monell, 1879) (Hemiptera, Aphididae)

Ejup Çota

Description and biological cycle: Small (1.5–2.0 mm), delicate, usually yellowish aphid with a knobbed cauda and bilobed anal plate. Nymphs usually have capitate dorsal hairs. Adult viviparous females (viviparae) are all alate. The life cycle is monoecious and holocyclic. Not ant-attended. Alate viviparae of *M.* (*Agriomyzus*) *castanicola* have a distinct dark medial stripe on head and thorax, black spots on abdomen, dark *siphunculi** and dark 2nd antennal segment. The dark pigmentation is less distinct in spring forms. Sides of pronotum and mesonotum of both species bear a black band extending from the eye to the base of hind wings. The late-summer form of *M*. (*Lineomyzocallis*) *walshii* has a broad foreground band of black pigment from the costal vein in the forewing, extending well past the stigma to the wing apex (*Photo left- alate viviparous female of summer form; right- ovipara in aautumn*). Mainly associated with *Quercus rubra*, the American red oak, but attacks other oaks of North American origin (*Q. coccinea, Q. palustris*) and one native species (*Q. robur*). Over-winters in the egg stage. Eggs hatch in the spring and give rise to the first of several asexual generations in which winged (alate) parthenogenic females give rise to wingless (apterous) nymphs that develop into alate parthenogenic females. In late fall, the sexual generation begins with production of apterous females (oviparae) and alate males. When mature and mated, the oviparae lay from 4–6 eggs/female in cracks and crevices among the bark, shortly before the leaves begin to fall.

Credit: Jan Havelka



Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2 - Cultivated areas of gardens and parks.

Native range: North America

Introduced range: *Myzocallis walshii* was detected for the first time in Europe in 1988 (France), and subsequently in several other European countries (Switzerland, Spain, Andorra, Italy, Belgium and Germany- *Map*).

Pathways: Accidental introduction with trade of ornamental plants.

Impact and management: Monitoring can be carried out using yellow sticky traps. As a mechanical means these exert limited control on populations. A number of aphicides can be used for chemical control as well as biological control agents, such as *Aphidoletes* spp, and *Aphidius spp*.

Selected references

Hullé M, Renoust M, Turpeau E (1998) New aphid species detected by permanent aerial sampling programmes in France. In: Nieto Nafria JM, Dixon AFG (Eds) Aphids in Natural and Managed Ecosystems. León, Spain: Universidad de León, Secretariado de Publicaciones. 365–369.

Remaudière G (1989) Découverte en France de l'espèce américaine *Myzocallis* (*Lineomyzocallis*) *walshii* (Monell) (Hom.Aphididae). Revue Francaise d'Entomologie: 14: 172.

14.37 – *Myzus persicae* (Sulzer, 1776) - Peach potato aphid (Hemiptera, Aphididae)

Olivera Petrović-Obradović

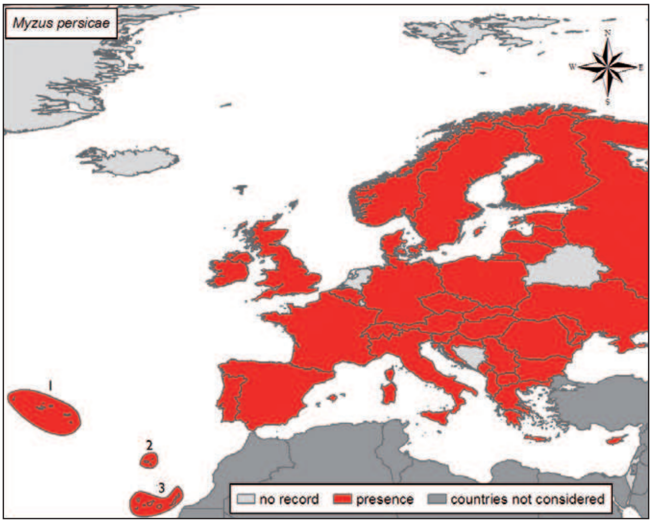
Description and biological cycle: Small to medium-sized aphid (1.2–2.1 mm), yellow-green, grey-green, pink or red, not shiny. The aphid on tobacco is usually red, as well as specimens kept in cold conditions. Winged forms have a black central dorsal patch on the abdomen. Both winged and wingless forms are present in colonies (*Photo left- Colony on tomato*). Situated on the underside of leaves, aphids excrete honeydew. They curl leaves of peach in spring (*Photo right*) and migrate on to many secondary hosts in summer. Many generations can be produced a year with very rapid development under favorable conditions. Highly polyphagous species. The sexual phase occurs on the primary host, *Prunus persica*. In glasshouses and where outdoor conditions are good, parthenogenetic development occurs all year round on secondary hosts. Secondary hosts are very numerous, feeding on plants in over 40 different families. Populations colonizing tobacco are recognized as subspecies *Myzus persicae nicotianae* (Blackman, 1987)**.**

Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; glasshouses; X7- Intensively-farmed crops interspersed with strips of spontaneous vegetation. X24- Domestic gardens of city and town centres; X25- Domestic gardens of villages and urban peripheries.

Native range: Unknown, possibly Asia.

Credit: Rémi Coutin/ OPIE



Introduced range: Cosmopolitan. Present since a very long time (since <1758) in Europe. Probably introduced repeatedly with infested plants.

Pathways: Plant trade.

Impact and management: Economically one of the most important aphids as it is a pest of many crops (peach, potato, tobacco, sugar beet, vegetables, ornamental plants). Also, among aphids, it is the most efficient vector of plant viruses, transmitting more than 100 nonpersistent and many important persistent viruses, including Potato leaf roll (PLRV), Bean leaf roll (BLRV), Pea enation mosaic (PEMV) and Beet yellow net (BYNV). For monitoring flight activity, yellow water traps and suction traps are used. For chemical control, since resistance to insecticide is easily developed, only a few new insecticides are sufficiently effective. Many predators act as biological controls in colonies of the pest, especialy Coccinelidae, Syrphidae, Chrysopidae, Miridae and Cecidomyiidae (*Aphidoletes aphidomyza* Rond.). A very rich parasitoid complex includes 18 species of Aphidiidae wasp. Two of them are used in control in glasshouses: *Aphididus colemani* Vier. and *Aphidius ervi* Hal.

Selected references

Balachowsky A, Mesnil L (1935) Les insectes nuisibles aux plantes cultivées. Paris, France: Mery L. 1921 pp.

Blackman RL, Eastop VF (2000) Aphids on the World's Crops - an Identification and Information Guide. 2nd edn. Chichester UK: John Wiley & Sons. 476 pp.

Theobald FV (1926)The plant lice or *Aphididae* of Great Britain, Vol I., London, UK: Headley Brothers. 372pp.

14.38 – *Prociphilus fraxinifolii* Riley ex Riley & Monell, 1879 - Woolly Ash Aphid (Hemiptera, Aphididae)

Olivera Petrović-Obradović

Description and biological cycle: Aphids 2.0–2.5 mm long, soft bodied, with well-developed wax glands, producing enormous quantities of wax rendering a snow-white appearance. *Siphuncular** pores are absent. Both winged (*Photo right*) and wingless forms have yellow-green to pale green bodies. Compact colonies inhabit curled leaves at twig tips throughout the vegetative period (*Photo left*). Host plant is red ash (*Fraxinus pennsylvanica*) and some other American species of *Fraxinus*. In North America, *P. fraxinifolii* is *holocyclic** but overwinters as parthenogenetic females in Europe. Host alternation does not occur.

Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): G1- Broadleaved decidous woodland; G5- Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland; I2- Cultivated areas of gardens and parks; X24- Domestic gardens of city and town centres; X25- Domestic gardens of villages and urban peripheries.

Native range: North America and Mexico.

Introduced range: First recorded in Europe in 2003 in Hungary, then in Serbia and Bulgaria (*Map*). Arrived three hundred years after introduction of its host plants, the American species of *Fraxinus*. Also introduced into Chile and South Africa.

Credit: Claude Pilon

Pathways: Trade of ornamental plants.

Impact and management: Very destructive aphid because deformation of curled leaves and twigs make trees much less attractive. Colonies also occur on ash roots, where overwintering occurs in Europe. Key pest in nursery production of *Fraxinus.* For monitoring, it is important to make inspections of ash in early spring and to use systemic insecticides as soon as colonies appear. Biological control involves *Aphelinus prociphili*, the parasitoid in North America; no parasitoids are found in Europe. The natural enemy complex fails to keep plant damage below an acceptable level.

Selected references

Petrović-Obradović O, Tomanović Ž, Poljaković-Pajnik L, Vučetić A (2007) An invasive species of aphid, *Prociphilus fraxinifolii* (Hemiptera, Aphididae, Eriosomatinae), found in Serbia. Archives of Biological Sciences, Belgrade 59: 9–10.

Remaudière G, Ripka G (2003) Arrival in Europe (Budapest, Hungary) of American ash aphid, *Prociphilus* (*Meliarhizophagus*) *fraxinifolii* (Hemiptera, Aphididae, Eriosomatinae, Pemphigini). Revue Francaise d'Entomologie 25: 152.

14.39 – *Toxoptera citricida* (Kirkaldy, 1906) - Tropical citrus aphid, oriental black citrus aphid, brown citrus aphid (Hemiptera, Aphididae)

Ejup Çota

Description and biological cycle: Aphid with medium-sized body, 1.5–2.4 mm long, shiny, reddish-brown to black. Alates (*Photo left*) can be identified, using a pocket lens, by the wholly black third antennal segment which is succeeded by a pale fourth segment. Median nervure of forewings normally forked twice. S*iphunculi** of alates about l/6 body length and strongly sculptured, while cauda rather bulbously rounded at apex. Apterous forms should be examined microscopically to observe the very long, fine and erect hairs on the legs and body margins. *Siphunculi** as in alates but relatively shorter (*Photo- right*). Cauda thick and bluntly rounded at the apex. Immature stages brown A useful character to distinguish *T. citricidus* from *T. aurantii* is that a distinct scraping sound produced by disturbed colonies of the latter, audible up to 45 cm away from the leaf, while *T. citricidus* are silent. Females are parthenogenetic and a single generation develops in 6–8 days. Tropical citrus aphids attack solely *Citrus* spp. Reproductive potential depends on the abundance of plant sap. About 30 generations are produced annually, depending on temperature. Winged females give rise to new infestations. Dark-brown to black colonies develop on young growths and are usually visited by ants.

Native habitat (EUNIS code): I - Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2 - Cultivated areas of gardens and parks; glasshouses.

Credit: Aphidweb.com

Native range: Occurs predominantly in humid tropical regions and presumably originated in south-east Asia.

Introduced range: First detected in Madeira in 1994, later observed in continental Portugal and Spain (*Map*).

Pathways: *T. citricidus* can spread locally by flight, but is very unlikely to be introduced into the region by natural means. Introduction occurs on potted plants and associated transportation materials.

Impact and management: Growth of shoots is greatly impaired and they become distorted; leaves become brittle and wrinkled and curl downwards. Attacked flowers fail to open or do so abortively since the ovaries are deformed. *T. citricidus* is an efficient vector of important virus diseases of citrus: citrus tristeza closterovirus, stem-pitting and seedling yellows strains. Control measures are intended to prevent damage to young shoots and fruits, and especially to suppress the formation of alates. Young trees are treated preventively with systemic insecticides. Many natural enemies are known (e.g. predators and entomopathogenic fungi). Some are being considered for use in integrated control programmes.

Selected references

Aguiar AMF, Fernandez A, Ilharco FA (1994) On the sudden appearance and spread of the black citrus aphid *Toxoptera citricidus* (Kirkaldy) (Homoptera Aphidoidea) on the island of Madeira. Bocagiana 168: 1–7.

Doncaster JP, Eastop JF (1956) The tropical citrus aphid. FAO Plant Protection Bulletin 4: 109–110.

Ilharco FA, Sousa-Silva CR, Alvarez Alvarez A (2005) First report on *Toxoptera citricidus* (Kirkaldy) in Spain and continental Portugal (Homoptera, Aphidoidea). Agronomia Lusitana 51: 19–21.

14.40 – *Scaphoideus titanus* Ball, 1932 - Vine leafhopper (Hemiptera: Cicadellidae)

Wolfgang Rabitsch

Description and biological cycle: Small leafhopper, average adult body size 5 mm, ochre-brown to mottled dark brown (*Photo*), nymphs yellowish-white with two dark brown spots on abdomen. Females lay clusters of 10–12 eggs in late summer in crevices in the bark of one- or two-year-old grapevine wood. Eggs overwinter, and development from first instar to adult takes 35–40 days. Adults of the new generation appear in late spring with one generation per year. Larvae and adults live *ampelophagously**, ie. monophagous on grapevine (*Vitis vinifera*).

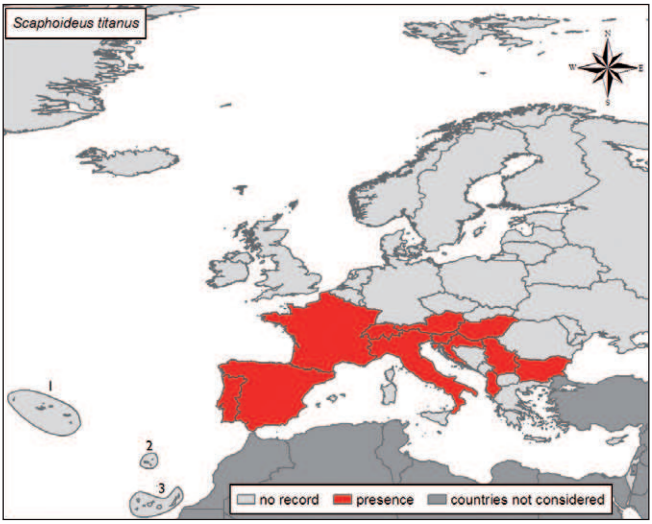
Native habitat (EUNIS code): I1- Arable land and market gardens.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens.

Native range: Nearctic species, originally present in the northeastern parts of USA and South Canada.

Introduced range: Unintentionally introduced to south-western France, presumably in the 1950s (first record in 1958), from where it subsequently spread to neighbouring countries: Italy (1963), western and southern Switzerland (1968), Slovenia (1983), Croatia (1987), northern Spain (1995) and northern Portugal (1999). Later, the species extended its range

Credit: Gernot Kunz



north- and eastward and was also found in Serbia (2003), southern Austria (2004), Bulgaria (2006), and southwestern Hungary (2006) (*Map*)

Pathways: Studies of the genetic structure of European populations has revealed long-distance translocations, most probably of eggs with grapevine propagation material. In addition the species spreads naturally, probably favoured by current climatic conditions.

Impact and management: *Scaphoideus titanus* is vector of "Flavescence dorée" (FD), a serious disease of grapevine, caused by the phytoplasma *Candidatus Phytoplasma vitis*, belonging to the elm yellow group 16Sr-V subgroups C and D. Larvae acquire phytoplasmas by feeding on infected plants and after 4–5 weeks (in the third larval stage), they are able to transmit the disease to healthy plants. FD phytoplasma is reported from France, Italy, Portugal, Serbia, Slovenia, Spain, and Switzerland. Productivity of infected plants is greatly reduced by discolouration (yellowing) and desiccation.

Selected references

Bertin S, Guglielmino CR, Karam N, Gomulski LM, Malacrida A, Gasperi G (2006) Diffusion of the Nearctic leafhopper *Scaphoides titanus* Ball in Europe: a consequence of human trading activity. Genetica 131: 275–285.

Seljak G (2008) Distribution of *Scaphoides titanus* in Slovenia: its new significance after the first occurrence of grapevine "flavescence dorée". Bulletin of Insectology 61: 201–202.

Steffek R, Reisenzein H, Zeisner N (2007) Analysis of the pest risk from Grapevine flavescence dorée phytoplasma to Austrian viticulture. EPPO Bulletin 37: 191–203.

14.41 – *Pulvinaria regalis* Canard, 1968 - Horse chestnut scale (Hemiptera, Coccidae)

Marc Kenis

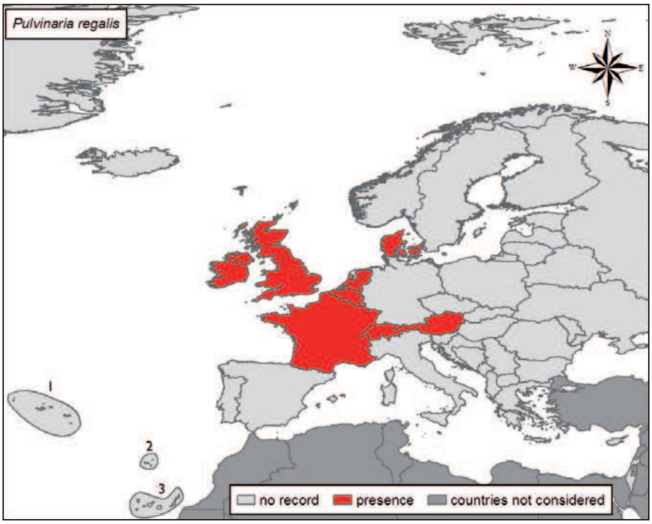
Description and biological cycle: Adult scales are dark brown, flattish, round and about 4 mm in diameter. They are found on the edge of white egg masses on bark of trunks and branches (*Photo*). Nymphs on foliage are pale yellow and oval in shape. At outbreak density, P. regalis can be recognized by their white egg masses covering the trunk and the main branches in spring and in summer. This scale is univoltine. Crawlers hatch in May and June and move to leaves of the host tree. Nymphs feed on leaves until September/October and then migrate to twigs where they overwinter in the third instar. In spring, newly emerged females first feed, then move to the main branches and the trunk to lay eggs. Crawlers can be transported by wind. Host plant transportation is probably another important mode of dispersal. Although *P. regalis* is known to attack a high number of woody plants, heavy infestations occur mainly on *Aesculus*, *Tilia* and *Acer* in urban and suburban areas or along roads.

Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; I2 - Cultivated areas of gardens and parks.

Native range: Unknown

Credit: Chris Malumphy



Introduced range: First found in London in 1964 and subsequently observed in France, Belgium, Netherlands, Germany, Ireland, Switzerland, Austria and Denmark (*Map*).

Pathways: Trade of ornamental plants.

Impact and management: Horse-chestnut scale does not kill trees, but outbreaks have a considerable impact on growth, particularly of young trees. This scale also causes aesthetic damage to ornamental trees. Additionally, it produces high quantities of honeydew that may become a nuisance in urban areas. Occurrence and incidence of the scale in natural habitats is unclear, and its interaction with native fauna is not known. Use of insecticides is possible, but difficult in urban areas. In spring, egg masses on trunks and branches can be washed off with water using a high-pressure cleaner. On small plants, mature scales and their eggs can be scraped or wiped from the stems.

Selected references

Hippe C, Frey JE (1999) Biology of the horse chestnut scale, *Pulvinaria regalis* Canard (Hemiptera: Coccoidea: Coccidae), in Switzerland. Entomologica 33: 305–309.

Jansen MGM (2000) The species of *Pulvinaria* in the Netherlands (Hemiptera: Coccidae). Entomologische Berichten 60: 1–11.

Speight MR. The impact of leaf-feeding by nymphs of the horse chestnut scale, *Pulvinaria regalis* Canard (Hom.: Coccidae), on young host trees. Journal of Applied Entomology 112: 389–399.

14.42 – *Leptoglossus occidentalis* Heidemann, 1910 - Western Conifer Seed Bug (Heteroptera: Coreidae)

Wolfgang Rabitsch

Description and biological cycle: Large coreid true bug, reddish brown with a white zig-zag band on the forewing and a characteristic leaf-like dilation on the hind tibia (*Photo*), average size of adults 18 mm. Adults emerge from overwintering sites in late spring. Females lay up to 80 eggs in chains on conifer needles. Nymphs develop into new generation in late summer, one generation per year. Feeds on the young seeds or flowers of conifer species, with a preference for Pinaceae (*Plinus* spp., *Pseudotsuga menziesii*), but it was also observed on *Picea*, *Cedrus*, *Abies* and *Juniperus*. *eptoglossus occidentalis* overwinters in crevices or secret places under bark or other structures.

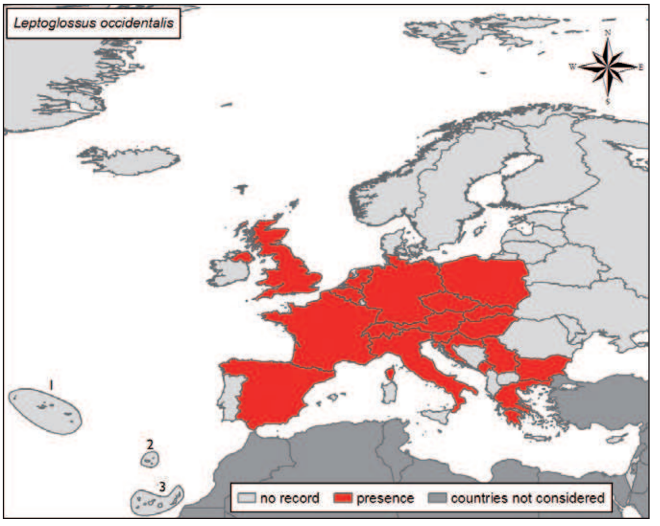
Native habitat (EUNIS code): G3 - Coniferous woodland; G3F - Highly artificial coniferous plantations.

Habitat occupied in invaded range (EUNIS code): G3 - Coniferous woodland; G3F - Highly artificial coniferous plantations; I2 - Cultivated areas of gardens and parks.

Native range: Presumed to be west of the Rocky Mountains in North America, from British Columbia to Mexico.

Introduced range: Since the 1950s, the species spread eastward and reached the east coast of North America in the 1990s. First European records date from 1999 near Vicenza (northern Italy). Western conifer seed bug then spread rapidly in Europe and is known from Switzerland (2002), Slovenia, Spain (2003), Croatia, Hungary (2004), Austria (2005), Czech Republic, France, Germany, Serbia (2006), United Kingdom, Belgium, Netherlands, Slovak

Credit: Wolfgang Rabitsch



Republic, Poland (2007), Bulgaria, Montenegro and Greece (2008) (*Map*). In most countries, rapid within-country spread and increasing abundance has been observed. Recently, it was also introduced to Japan.

Pathways: The species is capable of flying over long distances, but also is translocated as egg, nymph or adult with its host plant (conifers).

Impact and management: Enters buildings in large numbers in autumn and so becomes a nuisance. Feeding on conifers causes reduction of seed fertility, and the species is regarded as pest in the native range. Although no economic impact has yet been measured in Europe, first observations tend to show that it may largely decrease the potential of regeneration of conifers in both seed orchards and natural pine stands. Mechanical exclusion is recommended to avoid public nuisance.

Selected references

Bernardinelli I, Zandigiacomo P (2001) *Leptoglossus occidentalis* Heidemann (Heteroptera, Coreidae): a conifer seed bug recently found in northern Italy. Journal of Forestry Science, 47: 56–58.

Ishikawa T, Kikuhara Y (2009) *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae), a presumable recent invader to Japan. *Japanese Journal of Entomology (New Series)* 12: 115–116.

Lis JA, Lis B, Gubernator J (2008) Will the invasive western conifer seed bug *Leptoglossus occidentalis* Heidemann (Hemiptera: Heteroptera: Coreidae) seize all of Europe? *Zootaxa* 1740: 66–68.

14.43 – *Aspidiotus nerii* (Bouché, 1833) *(= A. hederae* (Vallot, 1829)) - Oleander scale (Hemiptera, Diaspididae)

Katalin Tuba and Ferenc Lakatos

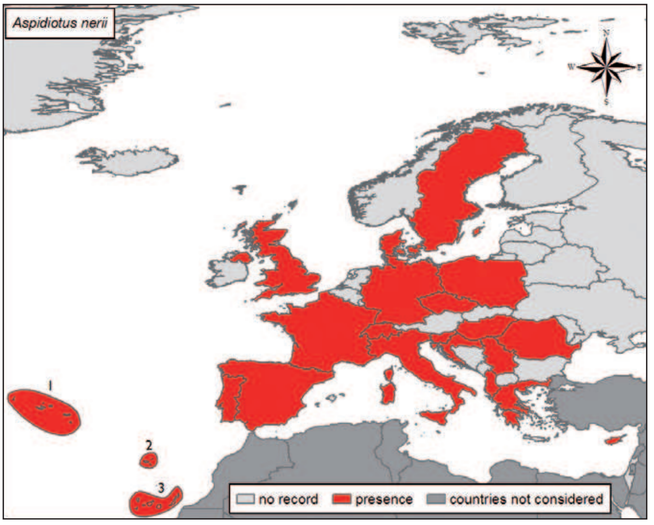
Description and biological cycle: Adult female covered with a scale that is 1.5–2.0 mm in diameter, nearly circular and flat, yellowish white with a yellow or gold central part. Female body bright yellow. Wings, legs, and eyes absent. Scale cover of male white, oval, translucent and smaller, and more elongate than female. Adult males winged. Highly polyphagous species; > 200 host species recorded including *Nerium oleander, Acer* spp., *Olea europaea*, *Populus* spp. *Ribes* spp. and *Vitis vinifera*. Attacks and can wholly cover leaves, bark and the fruits (*Photo- Colony on a palm leaf*). Reproduction is either sexual (*A. nerii nerii*) or parthenogenetic (*A. nerii unisexualis*). The sexual population has higher fecundity and faster development than the parthenogenetic one. There are two or three generations per year depending on climatic conditions. Development time is about 30–35 d influenced by the sex, temperature, humidity, and rainfall. Each female lays a total of 100–150 eggs under the scale of the female, where they develop. The settled female nymph moults twice, the males four times. Adult females remain under scale throughout their life. Males became winged after the second moult, but their flight ability is limited. Male lifespan is only a few hours.

Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; I8: Part of agricultural land and artificial landscapes.

Native range: Afrotropical region.

Credit: Claude Bénassy/INRA



Introduced range: Nowadays with worldwide distribution, occurring especially in tropical and subtropical zones. First record in Europe from Italy in 1829. At present, the oleander scale is observed in most of Europe (*Map*) but in cold areas, occurs only in greenhouses and indoors.

Pathways: Trade of ornamental plants. The wide geographical distribution of this pest is primarily due to human activities. The first instar, the only nymphal stage with legs, is active and responsible for short-distance dispersal.

Impact and management: : *Aspidiotus nerii* is particularly important where aesthetic value of the crop is high, like cut flowers, ornamentals in gardens, nurseries, under glass and indoors. After heavy infestation in olive orchards, quality and quantity reduces. Economically important on other mediterranean forest tree species too. Both adults and nymphs cause damage. Mechanical, chemical and biological control is used to reduce damage. Nowadays, biological control plays the most important role, especially in greenhouses. Natural enemies have already adapted to the species: parasitoids, e. g. *Aphytis chilensis* (attacking nymphs and adults in Europe, the Middle East, Africa, America and Australia), *Encarsia aurantii* (South America), and also predators, e.g. *Aleurodothrips fasciapennis* (attacking eggs, nymphs, adults), *Chilocorus circumdatus* (attacking nymphs and adults) and *Hemisarcoptes coccophagus* (attacking all stages, except eggs).

Selected references

Alexandrakis V, Bénassy C (1981) Experiment in biological control on olive in Crete using *Aphytis melinus* DeBach (Hym. Aphelinidae), parasite of *Aspidiotus nerii* Bouché (Hom. Diaspididae). *Acta Oecologica, Oecologia Applicata* 2: 13–25.

Gerson U, Hazan A (1979) A biosystematic study of *Aspidiotus nerii* Bouché (Homoptera: Diaspididae), with the description of one new species. *Journal of Natural History* 13: 275 – 284.

Longo S, Marotta S, Pellizzari G, Russo A, Tranfaglia A (1995) An annotated list of the scale insects (Homoptera: Coccoidea) of Italy. *Israel Journal of Entomology* 29: 113–130.

14.44 – *Diaspidiotus perniciosus* (Comstock, 1881) - San José scale (Hemiptera: Diaspididae)

Marc Kenis

Description and biological cycle: Female is grey, circular and about 2 mm in diameter (*Photo left- female with scale turned upside down to show the body colour*). Male has only forewings present. Larvae highly variable, depending on stage and sex, white to black, round to elongate, and fixed scales or little mobile yellow organisms (*Photo left- young nymphs pointed with arrow*). In Europe, two to four generations per year, depending on climatic conditions. In cold climates, the winter is usually spent in the first larval stage. Development starts in early spring. Females become adult after the second moult and gradually increase in size. Males have two larval instars, a prepupal and a pupal stage. Males are winged and fly, but lack mouthparts, whereas females remain stationary and feed. Females are viviparous and produce about 100 larvae, 30–40 d after copulation. First instar crawls to find new host tissues. Then, it attaches itself and secretes a waxy substance forming the scale cover. *Diaspidiotus perniciosus* is a highly polyphagous species. The main hosts are apples, peaches, pears (*Photo right- change in epidermis colour of a damaged pear*), plums and *Rubus.*

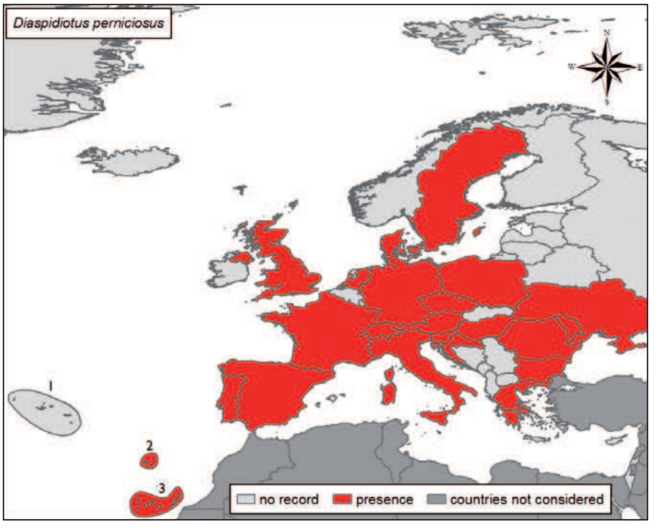
Native habitat (EUNIS code): G1- Broadleaved deciduous woodland; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): G1- Broadleaved deciduous woodland; I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; J100- glasshouses.

Native range: East Asia.

Introduced range: First introduced into California in the 19th century, from whence it spread to the whole North American continent. It is also present in many Asian, African and South American countries, as well as in New Zealand and Australia. First discovered in Hun-

Credit: Rémi Coutin/ OPIE (left), Claude Bénassy/ INRA (right)



gary and Italy in 1928 and now present in most European countries (*Map*) although in many of them, it has not yet reached its potential distribution.

Pathways: International spread probably occurs through human-mediated transport of planting material of trees and shrubs, or fruits. The crawling first instar larvae are the main dispersal stage and can be carried a few kilometres by wind. Adult males, but not females, can also be carried by wind.

Impact and Management: Various young host plant tissues are affected. Attacks occur on wood mainly, but also on leaves and fruits. The insect injects toxic saliva, causing localized discolouration. San José scale can kill a young tree in 2–3 years in the absence of control. Older trees are weakened and growth is reduced, as well as fruit production and quality. This is considered a serious orchard pest in several European countries, reducing growth, fruit quality and marketability.

Mineral oil can be applied in winter against overwintering stages, whereas pesticides during the growing season. Sex pheromone traps are used to monitor the timing and level of attack. Biological control with the aphelinid wasp *Encarsia perniciosi* has been carried out in several regions, with varying degrees of success.

Selected references

Kosztarab M, Kozár F (1988) *Scale insects of Central Europe*. Budapest, Hungary: Dr. W. Junk Publishers. 456 pp.

Mani E, Schwaller F, Baroffio C, Hippe C (1995) Die San-José-Schildlaus in der deutschen Schweiz: Wo stehen wir heute? Schweizerische Zeitschrift für Obst- und Weinbau 131: 264–267.

Melis A (1943) Contributo alla conoscenza dell'*Aspidiotus pernicious*. Redia 29: 1–170.

14.45 – *Pseudaulacaspis pentagona* (Targioni-Tozzetti, 1886) - Mulberry scale (Hemiptera: Diaspididae)

Katia Trencheva

Description and biological cycle: Adult female cover is convex, circular white (*Photo- Encrustation on a branch of peach*); shed skins usually sub-central, yellowish orange. Male cover smaller, felted, white, elongate, sometimes with slight median carina completely enclosing developing male; shed skin white, sometimes tinged with yellow. Body of adult female light yellow, eggs of male white, that of females yellow or pink. Mulberry scale reproduces sexually, with two to five generations per year depending on climate. It has three generations per year in Bulgaria, where overwintering occurs as a fertile female. In the USA, it can also overwinter as adult females or as eggs. Females each lay about 100 eggs, which hatch 3–5 days after oviposition.

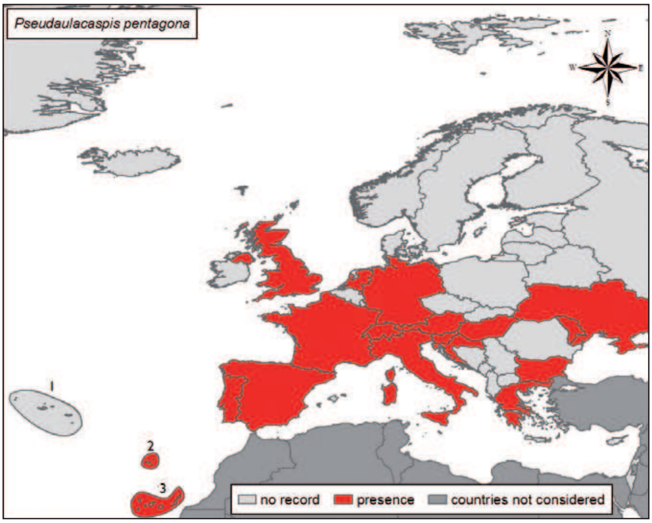
Native habitat (EUNIS code): G1- Broadleaved deciduous woodland; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): G1- Broadleaved deciduous woodland; I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks; J100- glasshouses.

Native range: East Asia.

Introduced range: Accidentally introduced to Italy in 1886, then recorded in most countries of Southern and Central Europe and in the Atlantic islands (*Map*). Nowadays, it is one of the best examples of the northward expansion of insects in central Europe where it has colonized both cultivated and natural habitats, primarily occurring on bark and fruit of various trees and shrubs, occasionally on leaves. Also introduced in Africa, Australia, New Zealand, southern Central America and many Pacific Islands.

Credit: ACTA/ INRA



Pathways: Trade in plants and plant products. Mulberry scale can also be transported by wind and by birds.

Impact and management: Most serious problems are caused in areas of accidental introduction in the absence of its natural regulators. The efficiency of natural enemies is reduced in urban areas by pollution. Consequently, *P. pentagona* can cause severe damage to ornamental plants in towns and cities. It is particularly destructive on flowering cherry, mulberry, peach and other deciduous fruit trees. In Europe, outbreaks have occurred in many countries, including Hungary, Switzerland, France, Greece and Bulgaria. Scale insects are difficult to control because the waxy or cottony covering serves as a protective barrier to traditional contact insecticides. However, a pest management program that incorporates natural, mechanical, and/or chemical controls should provide satisfactory control of most scales. Pheromone traps are used for detection in newly infested regions, especially in Europe. Colour and sticky traps have also been developed to monitor the flight and dispersal of males. Natural enemies, particularly the parasitoid *Encarsia berlesei*, can be effective control agents. Chemical control may not be advisable for orchards, since the natural enemies of *P. pentagona* can be killed, causing local outbreaks.

Selected references

Kozár F, Sheble DAF, Fowjhan MA (1995) Study on the further spread of *Pseudaulacaspis pentagona* (Homoptera: Coccoidea: Diaspididae) in Central Europe. Israel Journal of Entomology 29: 161–164.

Targioni Tozzetti A (1886) (1885) Sull'insetto che danneggia I gelsi. Rivista di bachicoltura 18: 1–3.

Watson GW (2002) *Pseudaulacaspis pentagona*. In: Arthropods of Economic Importance. Diaspididae of the world. World Biodiversity database. http://nlbif.eti.uva.nl/bis/diaspididae.php.

14.46 – *Metcalfa pruinosa* (Say, 1830) - Citrus Flatid Planthopper (Hemiptera: Flatidae)

Milka M. Glavendekić

Description and biological cycle: Adult usually 5.5–8 mm long and 2–3 mm wide. Adults vary from brown to grey. Forewings and the body are covered with a soft white powder, giving them a bluish tone (*Photo left*). Larvae white, less than twice as long as wide, when mature about 4 mm long (*Photo right*). The species is univoltine. Highly polyphagous, recorded on 330 woody and herbaceous plant species in 78 plant families in Europe. Eggs laid singly in splits under bark of host plant during late summer and early autumn, where they overwinter and hatch during spring of the following year between late May and early June to mid-July. First adults of the new generation appear from mid-July and live until early November.

Native habitat (EUNIS code): F5 - semi-arid and subtropical habitats

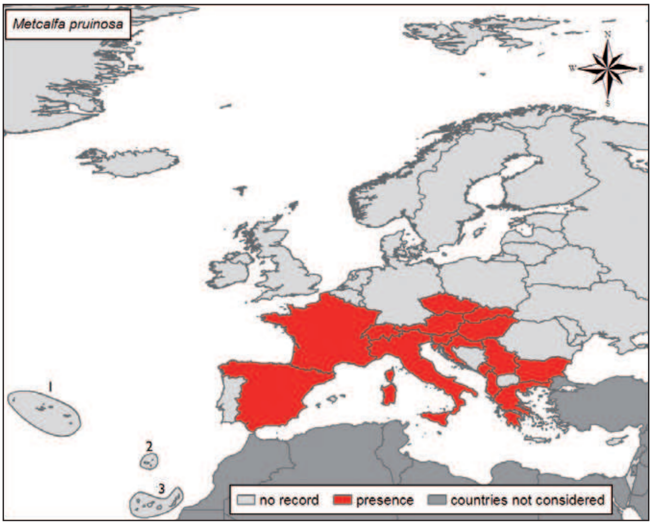
Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; I1 - Arable land and market gardens; I2 - Cultivated areas of gardens and parks; X16 - Land sparsely wooded with mixed broadleaved and coniferous trees; X25 - Domestic gardens of villages and urban peripheries.

Native range: Eastern North America.

Introduced range: Since it was first recorded in north-eastern Italy in 1979, citrus flatid planthopper has spread in the Mediterranean region, as well as to Central- and South-East Europe (*Map*).

Pathways: Trade appears to be the most likely pathway for introduction, on imported commodities such as nursery stock, both ornamentals and vegetables from infested areas.

Credit: LNPV/ Montpellier Station



Spread mostly passive through eggs laid into the bark of plants. Adults can also spread occasionally, attached to commodities or via transport by human activity.

Impact and management: Considered as one of the most prolific pests for its ability to infest a wide variety of plant species in agricultural, forest and urban ecosystems. *Metcalfa pruinosa* sucks the sap from small diameter stems, but the damage is usually minor. There is evidence in Italy that *M. pruinosa* is infected by *phytoplasma**, which could induce diseases on fruit trees. Oviposition injuries sometimes kill seedlings. Buds with deposited eggs could be frozen during winter. The most severe damage in Europe is caused by the secretion of honeydew which is colonized by sooty-mould fungus thus hindering photosynthetic capacity of the plant. High population could have a nuisance effect on tourism in some places. Mechanical control is effective on young plants by pruning and destroying shoots that contain oviposition punctures. Chemical control is possible in juvenile stages, but less effective against adults. Biological control includes the use of a dryinid wasp predator-parasitoid *Neodryinus typhlocybae* (Ashmead) (Hymenoptera: Dryinidae), which is introduced in Italy in 1994.

Selected references

Lucchi A (Ed) (2000) *La Metcalfa negli ecosistemi italiana*. Firenze: Agenzia Regionale per lo Sviluppo e l'Innovazione nel settore Agriocolo-forestale.163 pp.

Orosz A, Der Z (2004) Beware of the spread of the leafhopper species *Metcalfa pruinosa* (Say, 1830). Novenyvedelem 40: 137–141.

Trenchev G, Ivanova I, Nicolov P, Trencheva K (2007) *Metcalfa pruinosa* (Say, 1830) (Homoptera, Flatidae) a species new to the Bulgarian fauna. Plant Science 34: 195–198.

14.47 – *Nysius huttoni* White, 1878 - Wheat bug (Hemiptera: Lygaeidae)

Wolfgang Rabitsch

Description and biological cycle: Small lygaeid true bug, brown, with characteristic dorsal erect pubescence (*Photo- adults mating*). Average adult size 3.5 mm. Wing morphs comprise macropters, submacropters and brachypters; macropters are capable of flight over some distances; adults hibernate and two generations are developed per year in western Europe. Polyphytophagous species feeding on different weeds and crops (e.g. *Brassica*, *Capsella*, *Chenopodium*, *Hieracium*, *Medicago*, *Polygonum*, *Rumex*, *Silene*, *Senecio*, *Trifolium* and *Triticum*), attaining pest status in its native area.

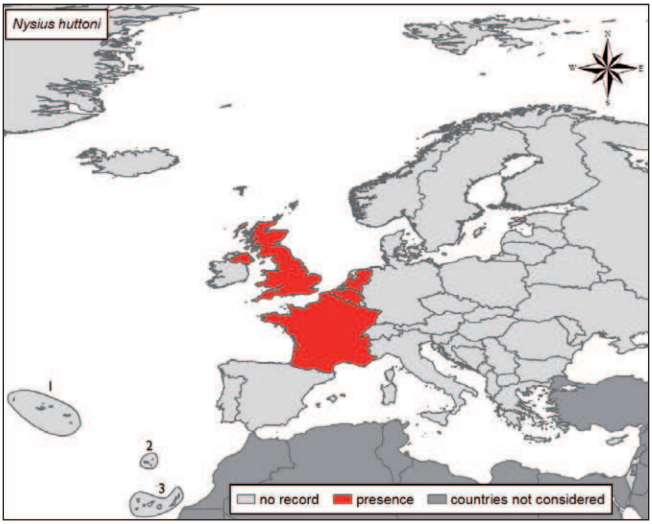
Native habitat (EUNIS code): B - Coastal habitats; E - Grassland and tall forb habitats; I - Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I - Regularly or recently cultivated agricultural, horticultural and domestic habitats. In Europe, found in dry and warm sites, waste grounds, roadsides, sparsely vegetated sandy soils, and abandoned fields. The presence of acrocarpous mosses seems necessary.

Native range: New Zealand.

Introduced range: First recorded 2002 in the Netherlands, 2003 in Belgium and subsequently found at the French/Belgian border. In 2007 and 2009 it was found in Great Britain

Credit: R. Kleukers



(East Suffolk, North Essex) (*Map*). *Nysius* species are well known for their high abundances and effective dispersal strategies and it is expected that this species will further spread across Europe. *Nysius huttoni* currently is included in the EPPO Alert List. It has been intercepted on fruits in Australia and the United States.

Pathways: Unintentional introduction, probably with shipments

Impact and Management: *N. huttoni* is an economically important pest species in New Zealand, particularly when feeding on wheat and degrading gluten thus diminishing baking quality. Insecticides may be used, but no effective control treatment is known.

Selected references

Aukema B, Bruers JM, Viskens G (2005) A New Zealand endemic *Nysius* established in the Netherlands and Belgium (Heteroptera: Lygaeidae). Belgian Journal of Entomology 7: 37–43.

He XZ, Wang Q, Carpenter A (2003) Thermal requirements for the development and reproduction of *Nysius huttoni* White (Heteroptera: Lygaeidae). Journal of Economic Entomology 96: 1119–1125.

Smit JT, Reemer M, Aukema B (2007) Een invasie van de nieuw-zeelandse tarwewants *Nysius huttoni* in Nederland (Heteroptera: Lygaeidae). Nederlandse Faunistische Mededelingen 27: 51–70.

14.48 – *Stictocephala bisonia* Kopp & Yonke, 1977 - Buffalo treehopper (Hemiptera: Membracidae)

Wolfgang Rabitsch

Description and biological cycle: Medium-sized membracid treehopper, average adult body size 8–10 mm, adults bright green (*Photo*), larvae light grey-green with longitudinal row of spines and conical abdomen. Characteristic pronotum with buffalo-horn-like protrusions. Females lay batches of 5–12 yellow eggs in the bark of host plants by cutting small punctures. Overwinters as eggs, with adults of the new generation appearing in July, and one generation per year. *Stictocephala bisonia* is polyphagous on different herbs, shrubs and trees (e.g. *Rosa*, *Malus*, *Pyrus*, *Prunus*, *Cornus*, *Crataegus*, *Populus*, *Ulmus*, *Coronilla*, *Melilotus*, *Solidago* and *Medicago*).

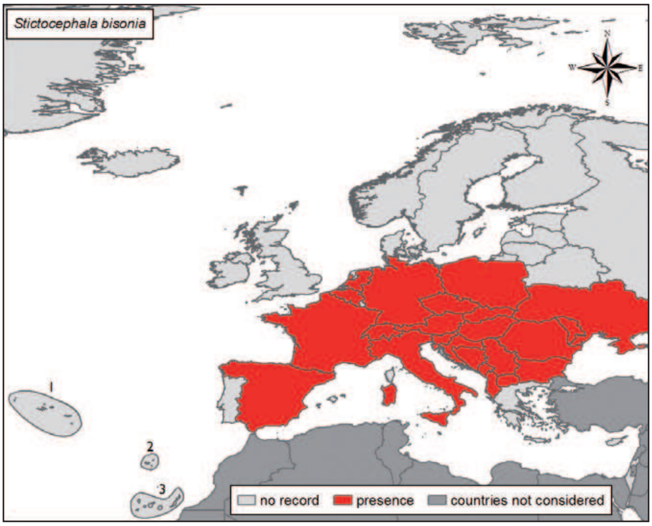
Native habitat (EUNIS code): F9 - Riverine and fen scrubs; I - Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): F9 - Riverine and fen scrubs; I - Regularly or recently cultivated agricultural, horticultural and domestic habitats; FA - Hedgerows; FB - Shrub plantations; E - Grassland and tall forb habitats. A preference for moist and wet riverine habitats, woody margins and tall herb stands, but it also can be found in dry meadows and agricultural land.

Native range: North America, widely distributed from Canada to Mexico.

Introduced range: accidentally introduced to Europe in the 20th century (first documented record: 1912 in former Hungary) and is present now in almost all countries (*Map*). It also spread to North Africa and Central Asia.

Credit: Wolfgang Rabitsch



Pathways: Long-distance dispersal of eggs with infected tree-seedlings; adults capable of flight.

Impact and management: Females deposit their eggs in shrub and tree stems, which usually die above the insertion slits and also provide entry for pathogens; this may cause economic loss in orchards and vine cultures. Feeding activity on fruit trees and in vineyards may cause discolouration and wrinkling of the leaves and malignant growth of twigs; severely scarred branches should be pruned out. Application of insecticides usually is not effective; release of an introduced Nearctic parasitoid braconid (*Polynema striaticorne*) successfully controlled *Stictocephala* populations in Italy, where the braconid established and spread subsequently.

Selected references

Alma A, Arno C, Vidano C (1987) Particularities on *Polynema striaticorne* as egg parasite of *Stictocephala bisonia* (Rhynchota, Auchenorryncha). Proceedings 6th Auchenorryncha Meeting, Turin, Italy, 7–11 September 1987, 597–603.

Fursov VN (1994) New data on *Polynema striaticorne* (Hymenoptera, Mymaridae) and its cicada host *Stictocephala bisonia* (Homoptera, Membracidae). Vestnik Zoologii 2: 12–19.

Holzinger W, Kammerlander I, Nickel H (2003) The Auchenorrhyncha of Central Europe. Vol. 1. Leiden: Brill. 674 pp.

Schedl W (1991) Invasion der Amerikanischen Büffelzikade (*Stictocephala bisonia* Kopp & Yonke, 1977) nach Österreich (Homoptera, Auchenorrhyncha, Membracidae). Anzeiger für Schädlingskunde 64: 9–13.

14.49 – *Halyomorpha halys* (Stål, 1855) - Brown Marmorated Stink Bug (Heteroptera: Pentatomidae)

Wolfgang Rabitsch

Description and biological cycle: Large pentatomid true bug, shield-shaped, mottled brown, size of adults 12–17 mm; females lay egg clutches of up to 25 eggs on the underside of leaves. The species hibernates as adult, producing one generation per year and is regarded as a polyphagous horticultural pest, observed on over 60 host plants, including fruit and shade trees and other woody ornamentals (e.g. *Acer*, *Buddleja*, *Citrus*, *Malus*, *Morus*, *Paulownia*, *Prunus*, *Pyrus* and *Rosa*), vegetables and as an agricultural pest on various leguminous crops (e.g. soybean).

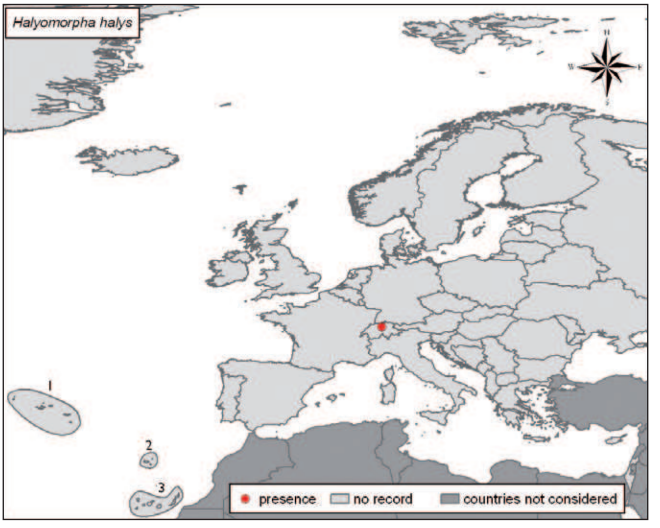
Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland; I - Regularly or recently cultivated agricultural, horticultural and domestic habitats; X25 - Domestic gardens of villages and urban peripheries.

Habitat occupied in invaded range (EUNIS code): I2 - Cultivated areas of gardens and parks; X25 - Domestic gardens of villages and urban peripheries.

Native range: Asia (Japan, Korea, China, Taiwan).

Introduced range: Introduced to the east coast of USA since 1996, where it subsequently spread along the east coast south to South Carolina. In 2007, there were several records including nymphs from the area around Zürich in Switzerland, indicating established populations in Europe.

Credit: Beate Wermelinger



Pathways: Long-distance dispersal occurs as stowaways with goods and plant material. Adults are able to fly some distance.

Impact and management: Detrimental impacts on ornamentals (necrosis on leaves and fruits) has been observed. Brown marmorated stink bug is also known to be a vector of witches' broom, a *phytoplasma** disease of *Paulownia tomentosa*, an East Asian ornamental tree introduced to Central Europe in 1834, which only recently established and spread in urban-industrial areas. In Asia and America, *Halyomorpha halys* causes a nuisance in households when seeking hibernation sites in large numbers in autumn. Mechanical exclusion and chemical control are suggested to control indoors pest problems.

Selected references

Hoebeke ER, Carter ME (2003) *Halyomorpha halys* (Stål), (Heteroptera: Pentatomidae) a polyphagous plant pest from Asia newly detected in North America. Proceedings of the Entomological Society of Washington 105: 225–237.

Wermelinger B, Wyniger D, Forster B (2008) First records of an invasive bug in Europe: *Halyomorpha halys* Stål (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees. Mitteilungen der Schweizerischen entomologischen Gesellschaft 81: 1–8.

Gyeltshen J, Bernon G, Hodges A. Brown Marmorated Stink Bug, *Halyomorpha halys* Stål (Insecta: Hemiptera: Pentatomidae). http://edis.ifas.ufl.edu/in623.

14.50 – *Viteus vitifoliae* (Fitch, 1855), Grape phylloxera (Hemiptera: Phylloxeridae)

Marc Kenis

Description and biological cycle: Small, globular, 1–1.8 mm long (*Photo*). Complex life cycle, which depends both on vine species or cultivars and the environment. Grape phylloxera has several generations per year and alternates between sexual and asexual generations, and between an aerial form causing galls on leaves, named *gallicolae*, and a root-feeding form, *radicicolae*. *Viteus vitifoliae* is a monophagous species restricted to some vine species of the genus *Vitis*. On the European grapevine, *Vitis vinifera*, the *gallicolae* form is rare, the *radicicolae* form persists parthenogenetically.

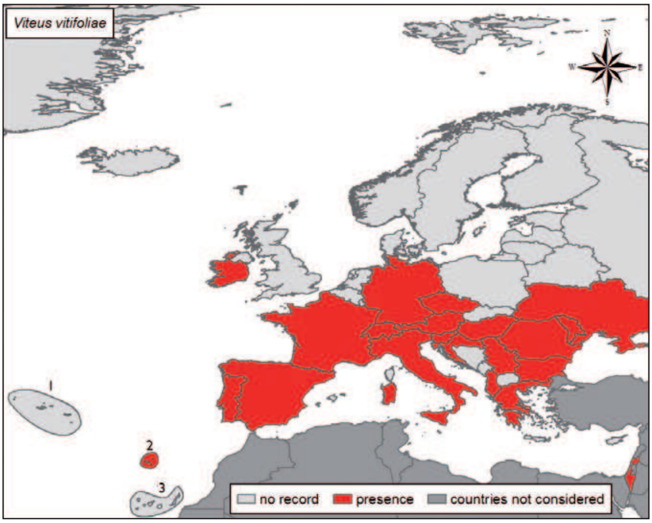
Native habitat (EUNIS code): G - Woodland and forest habitats and other wooded land; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Native range: Eastern North America.

Introduced range: It was first recorded in Europe in 1860 in France. Nowadays, most grapevine-growing areas in Europe are invaded, except Cyprus, parts of Greece and some re-

Credit: LNPV/ Montpellier Station



stricted areas in a few other countries (*Map*). The pest also spread to most major wine-producing areas, in Western North America, South America, South Africa and New Zealand.

Pathways: This aphid, particularly the *radicicolae* form, does not spread easily by itself and is mainly carried on grapevine plants.

Impact and management: The main damage is caused by *radicicolae* that feed on grapevine roots and are associated with secondary pathogens. In susceptible vine species and cultivars, they cause root rot, decrease plant vigour and, ultimately, kill the vines within 3–10 years. In the 19th century, *V. vitifoliae* causes huge damage to vineyards and has endangered the European wine industry. In France alone, it caused the destruction of 1.2 million ha. The problem was solved by grafting European cultivars on less susceptible American rootstocks. Grape phylloxera is still the target of phytosanitary regulations in Europe and elsewhere, because some pest-free areas remain, where susceptible grape cultivars are cultivated on their own roots. In the last 30 years, the level of damage has occasionally increased in various countries, with the appearance of new biotypes that overcome the resistance of certain rootstock cultivars.

Selected references

CABI (2007) Crop Protection Compendium. CD-ROM. Wallingford, UK: CAB International.

Forneck A, Walker MA, Blaich R (2001) An in vitro assessment of phylloxera (*Daktulosphaira vitifoliae* Fitch) (Hom., Phylloxeridae) life cycle. Journal of Applied Entomology, 125: 443–447.

Granett J, Walker MA, Kocsis L, Omer AD (2001) Biology and management of grape phylloxera. Annual Review of Entomology, 46: 387–412.

14.51 – *Corythucha arcuata* (Say, 1832) - Oak lace bug (Heteroptera: Tingidae)

Wolfgang Rabitsch and Marc Kenis

Description and biological cycle: Small tingid true bug, adults greyish to whitish with lacelike forewings, nymphs black with spines, adult body size 3 mm. Differs from *C. ciliata* in forewing pigmentation. Adults hibernate in bark crevices. Females lay eggs on the leaf underside. Development from egg to adult takes 30–45 days, 2–4 generations per year. The species feeds on deciduous *Quercus* species and was also reported on *Castanea sativa*, and occasionally on *Acer*, *Malus* and *Rosa* species.

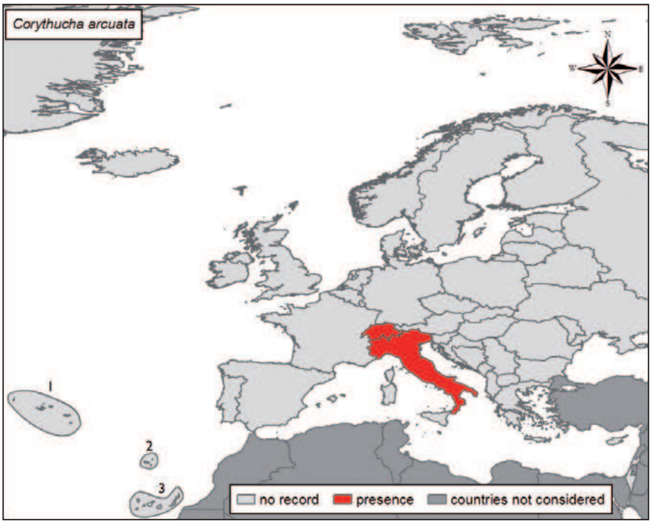
Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; I2 - Cultivated areas of gardens and parks.

Native range: North America, east of the Rocky Mountains.

Introduced range: First record for Europe dates back to spring 2000, when the species was found in northern Italy (Lombardy, Piemont). In 2002, it was found in Turkey (Western Anatolia) and 2003 in southern Switzerland (Tessin). It subsequently expanded its range in

Credit: Joseph Berger, insectimages.org



Italy and Switzerland and particularly in Turkey, where it has so far invaded an area of 28,000 km^2. The oak lace bug is expected to further spread in Europe, where host plants occur.

Pathways: Long-distance dispersal occurs with human activity (introduction with oak plants); adults can fly and be spread by wind.

Impact and management: *Corythucha arcuata* may cause damage to the host trees (chlorotic discolouration, desiccation, premature leaf-fall and reduced photosynthetic activity). *C. arcuata is* not considered an important pest species in North America, likely due to control by natural enemies. Since these are missing in Europe, the environmental and economic impact in Europe is unknown, but potentially high.

Selected references

Bernardinelli I (2000) Distribution of *Corythucha arcuata* (Say) in northern Italy (Heteroptera, Tingidae). Redia 83: 157–162.

Bernardinelli I (2006) Potential host plants of *Corythucha arcuata* (Het., Tingidae) in Europe: a laboratory study. Journal of Applied Entomology 130: 480–484.

Forster B, Giacalone I, Moretti M, Dioli P, Wermelinger B (2005) The American oak lace bug *Corythucha arcuata* (Say) new to southern Switzerland. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 78: 317–323.

14.52 – *Corythucha ciliata* (Say, 1832) - Sycamore lace bug (Heteroptera: Tingidae)

Wolfgang Rabitsch and Jean-Claude Streito

Description and biological cycle: Small tingid true bug, adults whitish with lacelike forewings, nymphs black with spines, average adult body size 3.5 mm. Adults hibernate under loose bark of their host trees. Females lay up to 350 eggs. Development from egg to adult takes 45 d, 1–3 generations per year. Sycamore lace bug feeds on different *Platanus* species (Platanaceae). In the introduced range, it is regularly found on *P. occidentalis* and *P. orientalis* and their hybrid *P. acerifolia*, used as an ornamental tree in cities.

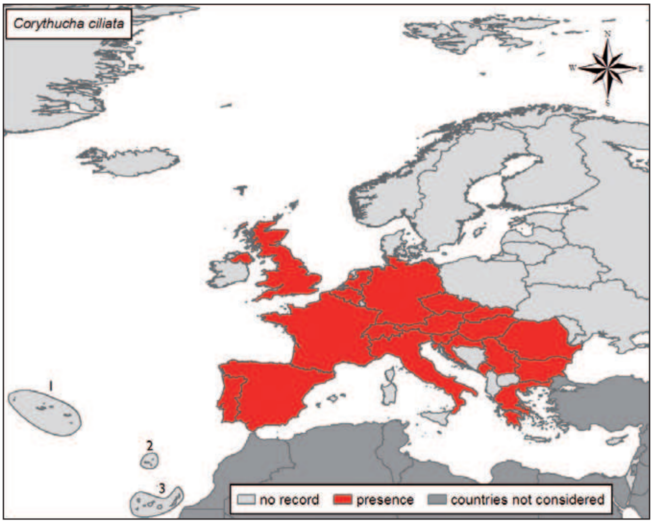
Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland.

Habitat occupied in invaded range (EUNIS code): I2 - Cultivated areas of gardens and parks; X22 - Small city centre non-domestic gardens; X24 - Domestic gardens of city and town centres.

Native range: North America, east of the Rocky Mountains.

Introduced range: First record for Europe dates back to 1964, when found in northern Italy (Padua). It is now distributed over much of Europe with records in the west (Portugal), north (United Kingdom) and east (Russia) (Map). Sycamore lace bug was also introduced to China, Korea, Japan, Australia and Chile.

Credit: Wolfgang Rabitsch



Pathways: Long-distance dispersal occurs with human activity (transport via vehicles or clothes). The species flies well and also drifts passively by wind.

Impact and management: *Corythucha ciliata* may cause damage to host trees (chlorotic discolouration, desiccation, premature leaf-fall, reduced photosynthetic activity, and prompt secondary infections by fungi and pathogens). In addition, the species may become a nuisance to people in parks and gardens, but usually impacts are of aesthetic value only. Chemical treatment with insecticides is not recommended.

Selected references

Arzone A (1986) Spreading and importance of *Corythucha ciliata* (Say) in Italy twenty years later. Bulletin WPRS, Section Régionale Ouest Paléarctique 9: 5–10.

Servadei A (1966) Un Tingide nearctico comparso in Italia (*Corythucha ciliata* Say). Bollettino della Societa Entomologica Italiana 96: 94–96.

Stehlík JL (1997) *Corythucha ciliata* (Say), a pest of plane trees, now also in the Czech Republic (Tingidae, Het.). Acta Musei Moraviae, Scientiae Naturales 81: 299–306.

14.53 – *Cales noacki* Howard, 1907 (Hymenoptera, Aphelinidae)

Jean-Yves Rasplus

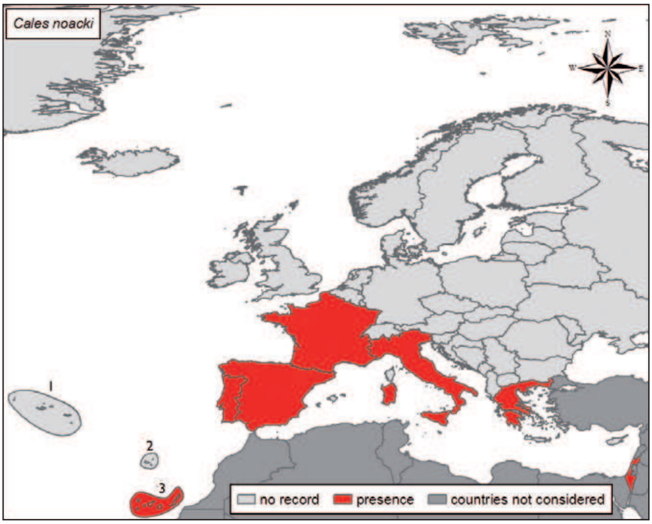
Description and biological cycle: Traditionally, the genus *Cales* has been placed in the family Aphelinidae but this position has changed several times. Indeed, within aphelinids, the genus exhibits four-segmented tarsi, straight fore tibial spur, narrow forewing, flagellum with three funicular segments, and unsegmented *clava**. Furthermore, the genus does not group with other Aphelinidae in a molecular phylogeny of chalcid wasps. *Cales* is the only genus of the subfamily Calesinae and comprises three described species that are parasitic on whiteflies, including *Cales noacki*, an endoparasitoid of woolly whitefly, *Aleurothrixus floccosus* (Maskell), a serious pest of citrus trees worldwide. *C. noacki* has a preference for second stage nymphs of this whitefly (*Photo- C. noacki laying eggs on A. floccosus*). However, *C. noacki* is not species specific and can develop on several species of whiteflies. At 26°C, the biological cycle of *C. noacki* takes about 21–22 days to be completed. *C. noacki* has always been regarded as a single species, however recent molecular analyses suggest that at least three distinct haplotypes coexist in the biocontrol citrus grove at Riverside. These species have different biology and environmental preferences.

Native habitat (EUNIS code): G1-Broadleaved deciduous woodlands; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats

Native range: South America.

Credit: Jean Pierre Onillon / INRA Antibes



Introduced range: *Cales noacki* strains released in Europe came from Chile, where they were sampled through biological control projects in the 1970s. The species was thus introduced in France (1971), Spain (1973), Portugal (1977), Italy (1980) and Greece (1991) for inoculative biological control *of* the woolly whitefly, *Aleurothrixus floccosus* (*Map*).

Pathways: Intentionnal introduction for biological control.

Impact and management: *C. noacki* is now established in Europe and has proved very effective against the woolly whitefly. The parasitoid has rapidly achieved high rates of parasitization (> 90%) resulting in substantial mortality to populations of the invading whitefly. In some parts of the Mediterranean area, the introduction of *Cales noacki* as a classical biological control agent against the woolly whitefly, may have led to the partial or complete displacement of native parasitoids of the non-target whitefly species *Aleurotuba jelinekii.*

Selected references

Onillon JC (1973) Possibilités de régulation des populations d'*Aleurothrixus floccosus* Mask. (Homopt. Aleurodidae) sur agrumes par *Cales noacki* How. (Hymenopt. Aphelinidae). Bulletin de l'Organisation Européenne et Méditerranéenne pour la Protection des Plantes 3: 17–26.

Viggiani G (1994) Recent cases of interspecific competition between parasitoids of the family Aphelinidae (Hymenoptera: Chalcidoidea). Norwegian Journal of Agricultural Sciences Supplement 16: 353–359.

Spicciarelli R, Tranfaglia A, Battaglia D, Torraco R (1996) Biological control of Aleurothrixus floccosus with Cales noacki. Informatore Agrario 52: 67–70.

14.54 – *Lysiphlebus testaceipes* (Cresson, 1880) (Hymenoptera, Braconidae)

Jean-Yves Rasplus

Description and biological cycle: Small (<3 mm) dark greenish to black braconid wasp. Female lays an egg on an aphid (*Photo- female laying eggs on rose aphid, Macrosiphum rosae* (*L.*)) the endoparasitoid larva grows and transforms it into a dead brown mummy. Development takes about 14 d; the wasp exits from a hole cut in the top of the mummy. *Lysiphlebus testaceipes* has a 2 days adult lifespan. Females produce 1.8 offspring per aphid patch, spending relatively shorter time on larger groups, while distributing a total of ca. 200 eggs across many patches (Tentelier et al., 2009). *L. testaceipes* is a generalist parasitoid, exhibiting extremely broad host range (> 200 aphid species on various plants that host notable aphid pests such *Aphis, Brachycaudus, Myzus*). In natural habitats, Aphidiinae are the main components of parasitoid communities controling aphid populations. Several species have been used for biological control in greenhouses.

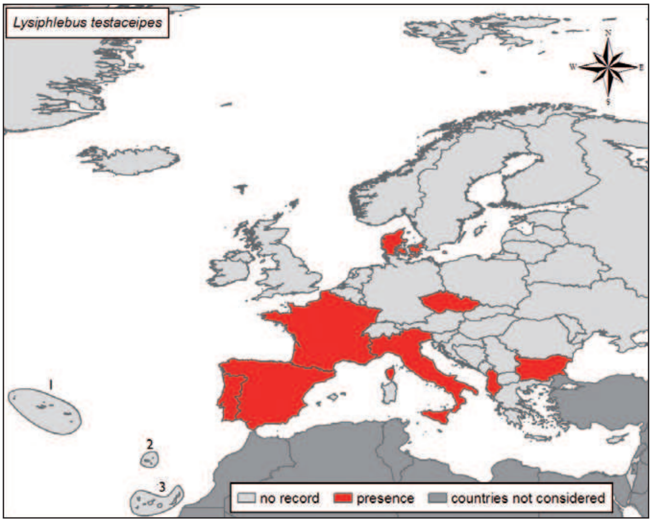
Native habitat (EUNIS code): E- Grassland and tall forb habitats; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Native range : Possibly Cuba.

Introduced range: Introduced into Europe (France) from Cuba in the 1970s to control *Aphis spiraecola* Patch, a pest of *Citrus* (Stary et al., 1988). This braconid soon became

Credit: Peter J. Bryant



established and subsequently spread in the Mediterranean basin, shifting to other native aphid species, and reaching Italy in 1977, Spain (1982–1984), Portugal (1985) and Greece (2002) (*Map*).

Pathways: Intentionnal introduction for biological control

Impact and management: In Europe, *L. testaceipes* is mass-reared, sold and released to control *Aphis gossypii* Clover. This braconid is a very efficient parasitoid that can reduce host infestations. However, recent studies have clearly shown that *L. testaceipes* outcompetes indigenous Aphidiinae. For example, on *T. aurantii*, it may have displaced two congeneric parasitoid species, *L. fabarum* (Marshall) and *L. confuses* Tremblay & Eady (Tremblay 1984). Such collateral effects on local faunas need more studies to estimate better the impact of this species on the parasitoid community foodweb associated with aphids.

Selected references

Stary P, Lyon JP, Leclant F (1988) Biocontrol of aphids by the introduced *Lysiphlebus testaceipes* (Cress.) (Hym., Aphidiidae) in Mediterranean France. Journal of Applied Entomology 105: 74–87.

Tremblay E (1984) The parasitoid complex (Hymenoptera: Ichneumonoidea) of *Toxoptera aurantii* (Homoptera: Aphidoidea) in the Mediterranean area. Entomophaga 29: 203–209.

Tentelier C, Lacroix MN, Fauvergue X (2009) Inflexible wasps: the aphid parasitoid *Lysiphlebus testaceipes* does not track multiple changes in habitat profitability. Animal Behaviour 77: 95–100.

14.55 – *Dryocosmus kuriphilus* (Yasumatsu, 1951) - Chestnut gall wasp (Hymenoptera, Cynipidae)

Milka M. Glavendekić and Alain Roques

Description and biological cycle: Female black, 2.5–3 mm long (*Photo- left*). Legs, antennal scapus and pedicel, apex of clypeus and mandibles yellow brown. Antennae 14-segmented with apical segments not expanded into a club. Head finely sculptured. Scutum, mesopleuron and gaster highly polished, smooth. *Propodeum** with three distinct longitudinal *carinae**; propodeum and pronotum strongly sculptured. *Scutum** with two *notaulices** converging posteriorly. Radial cell of forewing "open". Eggs oval, milky white, 0.1–0.2 mm long, long-stalked. Full-grown larva 2.5 mm long, milky white, without eyes and legs. Pupa 2.5 mm long, dark brown. Monophagous on *Castanea* spp. and their hybrids, attacking *Castanea crenata* Sieb. et Zucc. (Japanese chestnut), *C. dentata* (Marsh.) (American chestnut), *C. mollissima* Blume (Chinese chestnut), *C. sativa* Mill. (European chestnut) and *C. seguinii* Dode (in China). Univoltine and *thelytokous** parthenogenetic species. Adults emerge from galls from end of May until end of July. Lifetime short (about 10 d). Females lay 3–5 eggs per cluster inside buds. Each female can lay > 100 eggs. Some buds contain 20–30 eggs. Embryonic development lasts 30–40 d. Early instar larvae overwinter inside chestnut buds. At the time of bud burst in spring, gall wasps induce formation of a 5–20 mm diameter green (*Photo right*) or rose-coloured gall, containing 1–7 or 8 small cells where early instars develop. Galls develop in mid April on new shoots, leaves and twigs. Larvae feed 20–30 d within the galls before pupation from mid-May to mid-July.

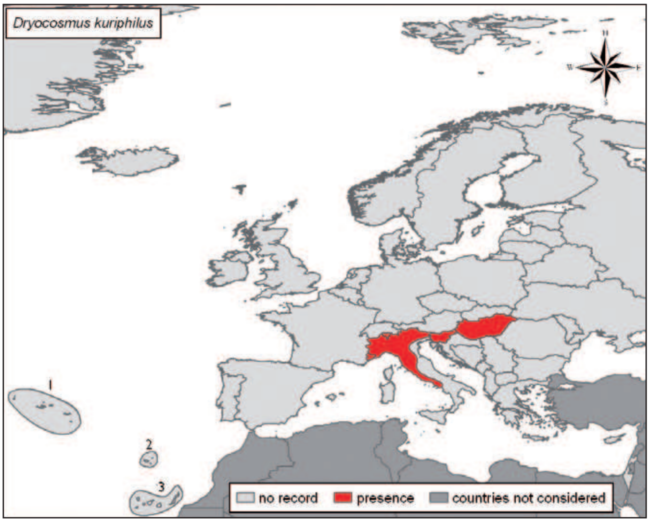
Native habitat: (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range: G1 - Broadleaved deciduous woodland; G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice. Chestnut forests and monocultures within coppice deciduous forests, chestnut orchards, lines of chestnut trees, gardens, ornamental cultures.

Native range: Asia (China).

Introduced range: In Europe, first recorded in 2002 near Cuneo, Italy, then from Slovenia (2006), France (Alpes- Maritimes, 2007) Switzerland (2009), Hungary (2009) and elsewhere in Italy (*Map*). Also introduced in Japan, Korea, and USA.

Credit: Milka Glavendekić



Pathways: Passive transport with plants for planting and cut branches. Dispersal at a local scale is realized by adult flight.

Impact and management: Chestnut gall wasp is the most severe worldwide insect pest on chestnuts. It disrupts twig growth and reduces fruiting, causing yield reduction up to 70%. Severe infestations may result in the decline and death of young chestnut trees and debilitate chestnut forests. Rapid recruitment of generalist parasitoids shared with oak cynipids suggests that chestnut gall wasp may have a negative impact on native cynipids through apparent competition. An effective measure would be to prohibit import of chestnut cut branches (or young plants) for grafting from China, Japan and America. In Italy, France and Slovenia, chestnut nurseries should be inspected annually to ensure trade of safe young plants. Infestations in small chestnut orchards may be reduced by pruning and destroying infested shoots. Treatment with systemic insecticides during the growing season at the place of production can be applied but is insufficient for control; as yet there are no efficient chemicals to control this pest. *Torymus sinensis* Kamijo was already introduced as a biological control agent in Italy from Japan. Several cultivars, prevalently belonging to the species *Castanea crenata* and its hybrids, are considered resistant; among them, Bouche de Bétizac (*C. sativa* x *C. crenata*) was reported. Larvae were found also in this cultivar but they die just at shooting time and do not develop galls. There are also new resistant Japanese and Korean chestnut cultivars.

Selected references

Csóka G, Wittmann F, Melika G (2009) The oriental sweet chestnut gall wasp (*Dryocosmus kuriphilus* Yasumatsu, 1951) in Hungary. Novenyvdelem 45: 359–360.

Forster B, Castellazzi T, Colombi L, Furst E, Marazzi C, et al. (2009) First record of the chestnut gall wasp *Dryocosmus kuriphilus* (Yasumatsu) (Hymenoptera, Cynipidae) in Southern Switzerland. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 82: 271–279.

Graziosi I, Santi F (2008) Chestnut gall wasp (*Dryocosmus kuriphilus*): spreading in Italy and new records in Bologna province. Bulletin of Insectology 61: 343–348.

14.56 – *Ophelimus maskelli* (Ashmead, 1900) - Eucalyptus gall wasp (Hymenoptera, Eulophidae)

Jean-Yves Rasplus

Description and biological cycle: Gall making wasp mostly attacking *Eucalyptus* species, with a preference for *E. camaldulensis* and *E. tereticornis* (= *umbellata* Smith.), but with a hostplant range encompassing 14 species of Eucalyptus belonging to three sections. Females can lay up to 100 eggs, usually in batches. They oviposit preferentially on the immature leaf blade close to the petiole, in the lower canopy. Each egg induces a small (about 1 mm diameter) pimple-like gall visible on both side of the leaf; galls are well separated (*Photo*). Gall density can reach 36 per cm^2 in Israel. *O. maskelli* has three generations per year in Israel and probably also in other Mediterranean countries (Protasov *et al* 2007).

Native habitat (EUNIS code): G1 Broadleaved deciduous woodland.

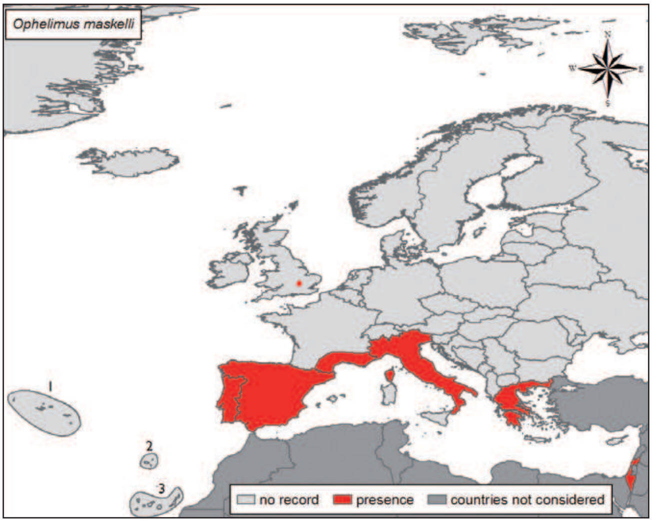
Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I2 - Cultivated areas of gardens and parks; X24 Domestic gardens of city and town centres.

Native range: Australia.

Introduced range: *O. maskelli*, erroneously reported as *O. eucalypti* (Gahan), has been introduced in the Mediterranean area since at least 2000. *O. maskelli* was first recorded in Italy (2000) (Arzone & Alma, 2000), then in Greece (2002), Spain (2003), UK (2004), France (2005), Portugal (2006) (*Map*). It also occurs in Israel and Turkey.

Pathways: Trade of ornamental plants.

Credit: Alain Roques



Impact and management: Heavy leaf galling can lead to premature shedding of leaves and dessication of large parts of tree crowns, resulting a depreciated value. Some Eucalyptus are particularly affected, such as *E. camaldulensis* planted for forestry in the Mediterranean region and the Middle East. Repeated attacks can lead to loss of foliage from terminal branches. Heavy galling can damage two thirds of the entire leaf volume and results in premature shedding of the leaves. The impact of the wasp on *E. camaldulensis* is consequently serious and heavily infested trees exhibit strong desiccation of their crowns and premature leaf drop. Interestingly, *O. maskelli* has similar host range to *Leptocybe invasa* Fisher & LaSalle, another Eulophid wasp developing on *Eucalyptus* and introduced in the Mediterranean basin from Australia. Adults emerge *en masse* in large clouds that cause nuisance and health problems to humans (Protasov *et al* 2007). *Closterocerus chamaeleon* (Hymenoptera Eulophidae) has been used to successfully control *O. maskelli* in Israel and also in Portugal. This wasp exhibits several biological traits that favour population increase and spread, such as *thelytoky**, high fecundity, short generation time, and high longevity that favours wind dispersion (Branco et al, 2009).

Selected references

Arzone A, Alma A (2000) A gall Eulophid of Eucalyptus in Italy. Informatore Fitopatologico 50: 43–46.

Branco M, Boavida C, Durand N, Franco JC, Mendel Z (2009) Presence of the Eucalyptus gall wasp *Ophelimus maskelli* and its parasitoid *Closterocerus chamaeleon* in Portugal: First record, geographic distribution and host preference. Phytoparasitica 37: 51–54.

Protasov A, La Salle J, Blumberg D, Brand D, Saphir N et al. (2007) Biology, revised taxonomy and impact on host plants of *Ophelimus maskelli*, an invasive gall inducer on eucalyptus spp. in the Mediterranean area. Phytoparasitica 35: 50–76.

14.57 – *Lasius neglectus* Van Loon, Boomsma & Andrásfalvy, 1990 - Garden Ant (Hymenoptera, Formicidae)

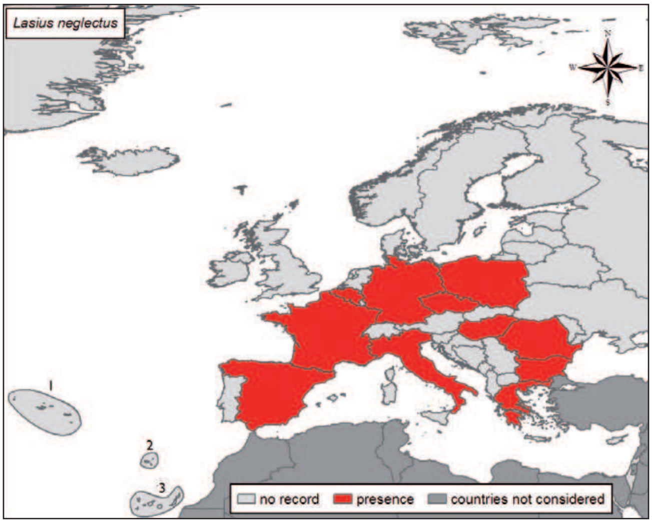
Wolfgang Rabitsch

Description and biological cycle: Ant with workers lacking erect hairs on the scape and extensor of hind tibiae, and with reduced mandibular dentition (*Photo*). Female immediately recognizable within European *Lasius* by its comparatively reduced size and proportionately smaller gaster, as compared with the thorax. Male the smallest of European *Lasius*. Sister species of *Lasius turcicus* Santschi. Ants are active throughout the entire day and aphid tending lasts for 24 h/d, from late April to late October, imposing a non-negligible cost on the energetic budget of individual trees. Nuptial flight seems to be absent. Nests are very difficult to delimit as they may coalesce and integrate a supercolony occupying enormous areas, as large as 16 ha. In urban areas, colonies are fragmented but may occupy a single tree. Finding many *dealate** queens (polygyny) in a nest is a key diagnostic of this species, the single polygynous European *Lasius* (s.str.). The number of queens depends on colony size, but estimated from queens found under stones, was about 35,500 in the Seva supercolony. Using soil cores, worker number for that population in May 2002 was estimated as 1.12×10^8. This species is truly unicolonial., with inter-nest and inter-population relationships showing a typical unicolonial trait of reduced level of aggressiveness. Areas occupied furnish a wide array of possible nesting sites: under stones, temporal refuges with aphids at the base of herbs, amid rubbish, etc. The expansion process of a colony seems to be much helped by the progressive urbanization of lots. This development usually implies the cutting and burning of all natural vegetation but trees. The planting of grass and continuous irrigation that follows favours ant establishment.

Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): I2 - Cultivated areas of gardens and park; X24- Domestic gardens of city and town centres. Populations live in a wide range of conditions, from strictly urban habitats, streets with heavy traffic to semi-urban sites, mildly

Credit: Jordan Wagenknecht, antbase.fr



degraded habitats or seemingly undisturbed localities. A common feature to all such places is the presence of trees, on whose aphid populations the ants depend.

Native range: Asia (possibly Turkey).

Introduced range: The species was described in 1990 (Van Loon *et al.* 1990), although its presence in the garden of the Company for the Development of Fruit and Ornamental Production at Budapest, Hungary, was already known from the early seventies (Andrásfalvy, in litt.). Colonies were later observed in Western, Central and Southeastern Europe (*Map*).

Pathways: Present distribution is likely to have been mediated by human intervention (commerce and transport of goods, soil, potted plants). Given the seeming absence of nuptial flight, dispersal capacity of this ant is very low. Local expansion is a very slow process and distances attained are two to five orders of magnitude smaller than minimum distances between known populations.

Impact and management: In areas occupied by this species, other surface-foraging ant species have vanished or have reduced populations. Other arthropod groups also seem to be affected in positive (increased abundance; aphids), negative (lower density; lepidoptera larvae) or neutral ways. Occupation of electrical conduits in homes may cause nuisance to people.

Selected references

Cremer S, Ugelvig LV, Drijfhout FP, Schlick-Steiner BC, Steiner FM et al. (2008) The Evolution of Invasiveness in Garden Ants. PLoS One 3 (12): e3838. doi-10.1371/journal.pone.0003838

Espadaler X, Tartally A, Schulz R, Seifert B, Nagy C (2007) Regional trends and local expansion rate in the garden invasive ant *Lasius neglectus* (Hymenoptera, Formicidae). Insectes sociaux 54: 293–301.

Van Loon AJ, Boomsma JJ, Andrásfalvy A (1990) A new polygynous *Lasius* species (Hymenoptera, Formicidae) from Central Europe. I. Description and general biology. Insectes Sociaux 37: 348–362.

14.58 – *Linepithema humile* (Mayr, 1868) - Argentine ant (Formicidae, Hymenoptera)

Wolfgang Rabitsch

Description and biological cycle: Light brown ant; females 4.5–4.9 mm long and workers 2.1–3.0 mm long (*Photo*) Omnivorous, feeding on honeydew, nectar, insects and carrion. Local dispersal by budding of large unicolonial nests (up to 150 m/year); long-distance dispersal human-mediated within the introduced ranges. Haplodiploid system with sterile workers; polygynous (multi-queened) nests; social organisation variable in its native range (from multicolonial to unicolonial), but entirely unicolonial in introduced range, with surface area covered by single supercolonies ranging from 2500 m^2 to many km^2. In the absence of queens, workers can lay unfertilised eggs, which develop into fully functional males. Prefers moderate temperature and moisture levels.

Native habitat (EUNIS code): G- tropical and subtropical natural forests.

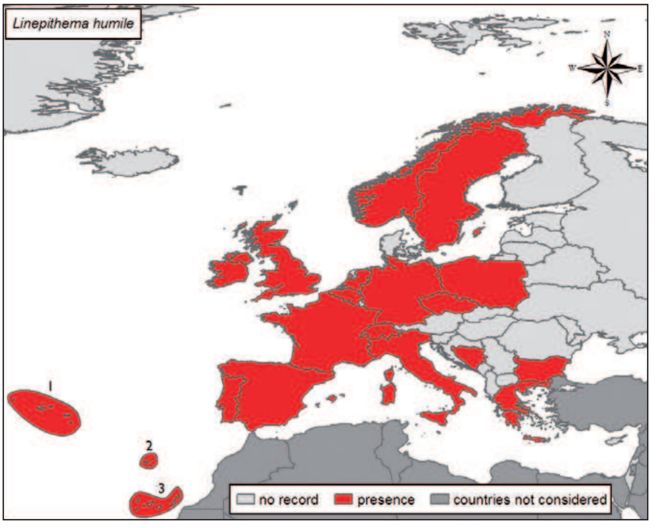
Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; G4- Mixed deciduous and coniferous woodland; preferably associated with disturbed, human-modified habitats in its introduced range, but may also invade natural habitats (e.g., oak and pine woodland in the Mediterranean basin).

Native range: South America.

Introduced range: The Argentine ant occurs throughout the world on all continents, especially in mediterranean-type climates, and many oceanic islands. First recorded in Europe in 1847 in Portugal, it invaded most of the Western Mediterranean Europe and Central Europe (*Map*). Ecological niche models predict that with changing climate, the species will expand at higher latitudes.

Pathways: Transported with vehicles (airplanes, ships) together with goods and materials, soil, plants, etc.

Credit: Alex Wild



Impact and management: Supercolonies, by reducing costs associated with territoriality, allow high worker densities and interspecific dominance in invaded habitats. It has displaced native ant species in many parts of the world, even leading to species extinction in some cases. Also competes with other arthropod species for resources (e.g., for nectar with bees) and reduces local arthropod diversity. Taxa other than arthropods are also affected (e.g., causes nest failure of birds). Ecosystem level impacts such as reduction of seed dispersal capacity and disruption of mutualistic associations with other species are documented. Regarded as a nuisance for tourism at some places on the Mediterranean coast. Tending behaviour may increase homopteran populations, causing some crop loss. However, these costs are considered to be low. Several chemicals have been applied via ant baits, including insect growth regulators. Application needs supervision to optimise results and to minimise side-effects on non-target species. Since Argentine ants prefer disturbed sites, any extensification of land use or reduction in monoculture may help prevent high densities.

Selected references

Carpintero S, Reyes-López J, Arias de Reyna L (2005) Impact of Argentine Ants (*Linepithema humile*) on an arboreal ant community in Donana National Park, Spain. Biodiversity and Conservation 14: 151–163

Giraud T, Pedersen JS, Keller J (2002) Evolution of supercolonies: The Argentine ants of southern Europe. Proceedings of the National Academy of Sciences 99: 6075–6079

Way MJ, Cammell ME, Paiva MR, Colligwood CA (1997) Distribution and dynamics of the argentine ant *Linepithema* (*Irydomirmex*) *humile* (Mayr) in relation to vegetation, soil conditions, topography and native competitor ants in Portugal. Insectes Sociaux 44: 415–433.

14.59 – *Nematus tibialis* Newman, 1837 - Locust sawfly, false acacia sawfly (Hymenoptera, Tenthredinidae)

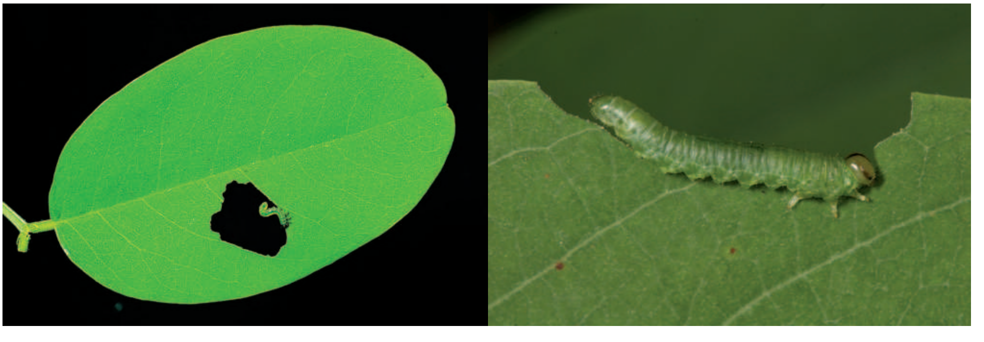
Milka Glavendekić

Description and biological cycle: Adult 6–7 mm long, head marked yellow above, thorax and abdomen marked with black; antennae black. Scutellum yellow. Legs yellow, exception of hind tibiae and tarsi, which are black and distinguish *Nematus tibialis* from the other sawflies. Larva green and shiny, 12 mm long with brownish-green head marked with black (*Photo right*). Feeds exclusively on black locust, *Robinia pseudoacacia* L., and its various ornamental cultivars, and on bristly locust *Robinia hispida* L. Adults emerge in May and June. Females deposit eggs in young leaflets and of the host plant. The young larvae feed on leaves, forming a small hole through the lamina (*Photo left*). Later, larvae consume more leaf area until maturity. Larval development last two to three weeks after which they enter the soil, forming tough dark brown cocoons, where they pupate. Adults emerge shortly afterwards. False Acacia sawfly develops a second generation in the late summer and sometimes a third brood in the autumn.

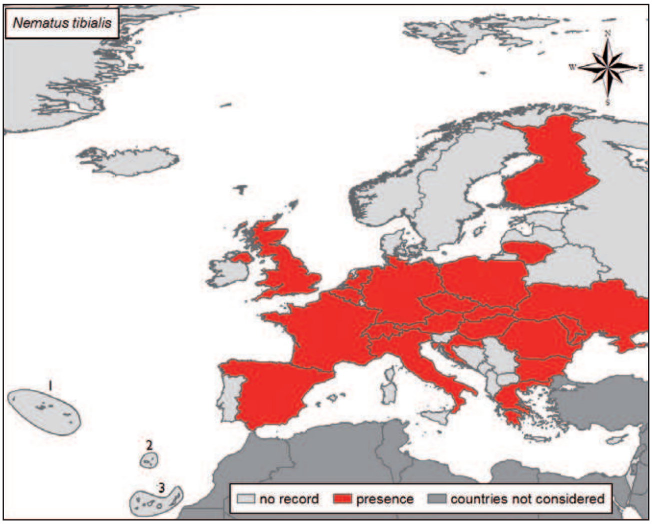
Native habitat (EUNIS code): G1- Broadleaved deciduous woodland; G4- Mixed deciduous and coniferous woodland; G5- Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice.

Habitat occupied in invaded range (EUNIS code): G1- Broadleaved deciduous woodland; G5- Lines of trees and, small anthropogenic woodlands: plantations of black locust aimed to stop erosion, recently felled woodland, early-stage woodland and coppice, in the green belt down highways and at all sites where black locust is growing like a weed; I2 - Cultivated areas of gardens and parks; X6- Crops shaded by trees on sites where wind erosion is managed by planting black locust.

Native range: North America (Pennsylvania).



Credit: György Csóka



Introduced range: First detected in Europe in 1825 in Germany. Then established in most countries of Western, Central and Southern Europe (*Map*).

Pathways: Plant trade for ornamental purposes (parks, gardening, bonsai).

Impact and management: Severe defoliation of leaves is common on black locust and bristly locust. Holed or partially devoured leaves on ornamental trees and nursery stock reduce ornamental value and health condition of young plants. *Nematus* also shares a leaf eating niche with several other invasive species, *Parectopa robiniella, Phyllonorycter robiniella, Obolodiplosis robiniella,* as well as with various aphids and mite species. Control measures are not needed in most cases. The survey of natural enemies revealed egg and larval parasitoids potentially available for biological control. The egg parasitoid *Trichogramma aurosum* Sugonjaev and Sorokina 1975 (Trichogrammatidae) is recorded from different locations in Central and Western Europe (Denmark, Netherlands, Austria, Luxemburg, Belgium and Germany). Impact is known on local fauna. A larval parasitoid *Lathiponus bicolor* (Brischke) (Ichneumonidae) has newly adapted to *N. tibialis* after switching from the congeneric native sawfly species, *Nematus salicis* L.and *N. yokohamensis* auct.

Selected references

Ermolenko VM, Sem'yanov VP (1981) Development of the fauna of sawflies (Hymenoptera, Symphyta) of man-made coenoses of cultivated lands in the south of the European part of the USSR. Noveishie dostizheniya sel'skokhozyaistvennoi entomologii (po materialam USh sëzda VEO, Vilnius, 9–13 October 1979.): 73–76.

Markovic C, Stojanovic A (2008) Finding of locust sawfly *Nematus tibialis* (Newman) (Hymenoptera, Tenthredinidae) in Serbia. Biljni Lekar 36: 131–135.

14.60 – *Megastigmus spermotrophus* Wachtl, 1893 - The Douglas-fir seed chalcid (Hymenoptera, Torymidae)

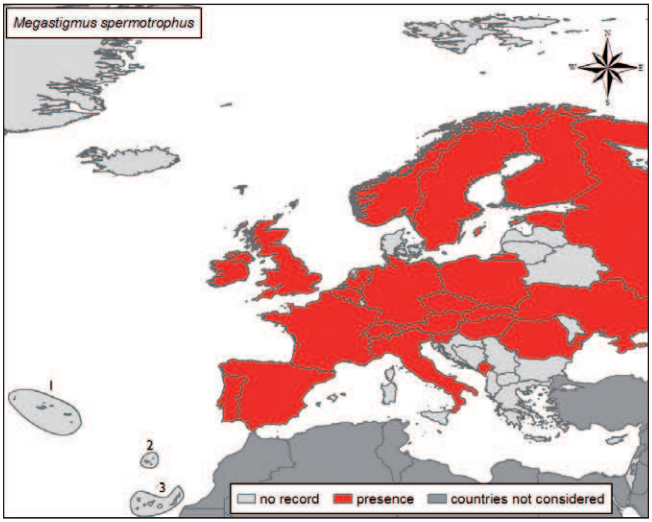
Alain Roques

Description and biological cycle: Female 2.8–4.3 mm long, body entirely brownish-yellow to orange- yellow with a few darker spots and an ovipositor as long as body (*Photo*). Male 2.7–3.8 mm long, with body colour dark lemon yellow with distinct black patterns on head, thorax, propodeum and first two abdominal segments. Adults emerge from late April to mid-June, depending on location. Oviposition occurs after the host plant cone becomes pendant, when its water content is near its maximum. Egg laying begins when a red-brown or purple margin appears on cone scales and lasts until the cone scale turns entirely red-brown. In seed orchards, the oviposition period may last up to 7 weeks. Most oviposition punctures are made on scale margins, resulting in conspicuous resin droplets. Eggs are laid directly into the seed. The hatching larva feeds on *archegonia**, then on cotyledons. The following larval instars progressively consume the *megagametophyte** (endosperm), which is entirely destroyed by July. Larvae can successfully develop in unpollinated, unfertilized seeds where they prevent megagametophyte abortion. Larval diapause may extend up to four years, but most individuals emerge during the first two years. The proportion of individuals in prolonged diapause is highly correlated with cone abundance in the year following larval development. Sex ratio is highly variable with location and year, usually ranging from 1:0.5–1:1.5. In North America, Douglas-fir seed chalcid attacks both varieties of Douglas-fir, *Pseudotsuga menziesii* (var. *glauca* and var. *menziesii*). In Europe, it has been found in *P. menziesii* and on other introduced *Pseudotsuga* species such as *P. macrocarpa* and *P. japonica*.

Native habitat (EUNIS code): G3 - Coniferous woodland.

Habitat occupied in invaded range (EUNIS code): G3 - Coniferous woodland; G4 - Mixed deciduous and coniferous woodland ; G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice ; I2 - Cultivated areas of gardens and parks; X11- Large parks; X15- Land sparsely wooded with coniferous trees ; X24- Domestic gardens of city and town centres.

Credit: David Lees



Native range: Western North America, from British Columbia to California and Mexico.

Introduced range: First recorded in Europe in Austria in 1893. Then, observed wherever Douglas-fir has been planted, even in Mediterranean countries (*Map*).

Pathways: Trade of tree seeds. The presence of larvae is is usually overlooked in traded seed lots, the infested seeds showing up only when X-rayed (*see Figure 12.10 in Chapter 12*).

Impact and management: In Europe, this species has few indigenous competitors and parasitoids. Thus, the proportion of seeds infested in European seed orchards can reach up to 95%, especially during years of light cone crops. During years of moderate to heavy cone crops, seed infestation varies between 10%-50%. However, the true impact of this insect on seed production is difficult to assess because larvae can complete development in unfertilized seeds. For example, in the absence of fertilization, no viable offspring would be produced from seed, but seed damage would be estimated at 100 %, because only chalcid-infested seeds can be found. Monitoring can be carried out using yellow traps baited with terpinolete. Chemical control is possible, but effective only against adults, whereas systemic insecticides give contrasting results for larvae concealed in the seeds. The introduction of parasitoids from the native range, e.g. the pteromalids *Mesopolobus* spp., may constitute an alternative, biological control.

Selected references

Aderkas P Von, Rouault G, Wagner R, Rohr R, Roques A (2005) Seed parasitism redirects ovule development in Douglas-fir. *Proceedings of the Royal Society of London* B, 272: 1491–1496.

Mailleux AC, Roques A, Molenberg JM, Grégoire JC (2008) A North American invasive seed pest, *Megastigmus spermotrophus* (Wachtl) (Hymenoptera: Torymidae): Its populations and parasitoids in a European introduction zone. Biological Control 44: 137–141.

Roques A., Skrzypczynska M (2003) Seed-infesting chalcids of the genus *Megastigmus* Dalman (Hymenoptera: Torymidae) native and introduced to Europe: taxonomy, host specificity and distribution. Journal of Natural History 37: 127–238.

14.61 – *Sceliphron curvatum* (Smith, 1870), *S. caementarium* (Drury, 1773) and *S. deforme* (Smith, 1856) (Hymenoptera, Sphecidae)

Jean-Yves Rasplus

Description and biological cycle: The genus *Sceliphron* comprises four species native to Europe. These large black or dark brown wasps, banded with yellow, have thin waist and long legs. In summer, females are seen collecting mud to build their nests composed of several cells (*Photo- nest of S. curvatum* in Austria). The adult wasp preys on spiders that are packed into the cells, the female lay an egg in the cell and the larva develop at the expense of the stored spiders. During the last 100 years, three alien species of *Sceliphron, S. caementarium*, *S. curvatum* and *S. deforme,* have been introduced to Europe, which are treated together here.

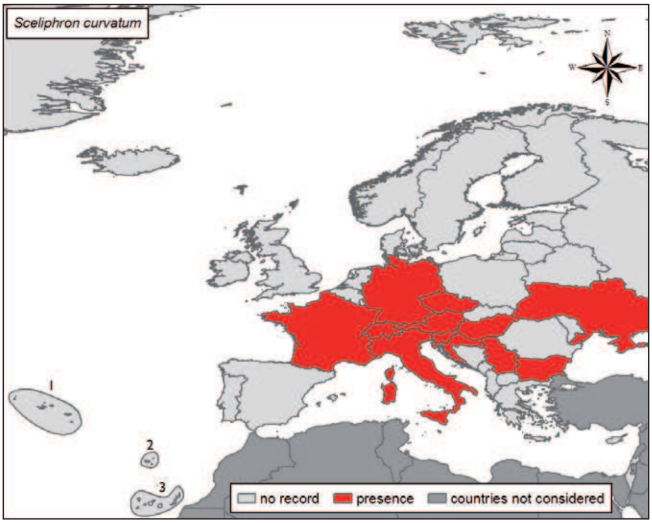
Native habitat (EUNIS code): C3- Littoral zone of inland surface waterbodies; G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): C3- Littoral zone of inland surface waterbodies; X25- Domestic gardens of villages and urban peripheries

Native range: *S.* (*S.*) *caementarium* is originally native to North America, whilst the two other species belong to another subgenus (*Hensenia*) which is mostly Asiatic and Australasian.

Introduced range: *S. caementarium* has been accidentally introduced several times into Europe during the 19th and 20th centuries. The species was first reported in 1945 from Versailles (but was never reported there again) and in 1949 from southern France. Since the 1970s, it

Credit: Christine Sinhuber, www.aculeata.de



is well established and occurs in several countries (France, Spain, Portugal and Ukraine). *S. curvatum* was first observed in Austria in the 1970s, where it was probably introduced by human activities. It subsequently spread all over central and southern Europe. The species is now reported from most of southern Europe (France, Italy, Greece), but has also reached northern countries (Netherland, Germany and Czech Republic) (*Map*). The species probably dispersed on its own following large river valleys, and has reached Mediterranean areas where it finds conditions ecologically similar to its native range. It is mostly associated with urban areas, where it constructs nests in different places of the houses. In southern areas, *S. deforme* may have several overlapping generations. *S. deforme,* a species naturally distributed in central and tropical Asia, is also reported from several east Mediterranean countries: Bulgaria, Greece, Italy and Montenegro.

Pathways: Unknown.

Impact and management: *S. caementarium* and *S. curvatum* probably threaten native *Sceliphron* species in France and Austria. However, the impact of *S. curvatum* on indigenous *Sceliphron* species is still poorly understood and needs further study.

Selected references

Bitsch J, Barbier Y (2006) Répartition de l'espèce invasive *Sceliphron curvatum* (F. Smith) en Europe et plus particulièrement en France (Hymenoptera, Sphecidae). Bulletin de la Société entomologique de France 111: 227–237.

Cetkovic A, Radovic I, Dorovic L (2004) Further evidence of the Asian mud-daubing wasps in Europe (Hymenoptera: Sphecidae). Entomological Science 7: 225–229.

Gepp J (2003) Verdrängt die eingeschleppte Mauerwespe *Sceliphron curvatum* autochthone Hymenopteren im Südosten Österreichs? Entomologica Austriaca 8.

14.62 – *Vespa velutina nigrothorax* du Buysson, 1905 - Asian yellow-legged hornet (Hymenoptera, Vespidae)

Claire Villemant, Quentin Rome et Franck Muller

Description and biological cycle: Black brown hornet, 20–35 mm long, with gastral segments bordered with a fine orange band, except the 4th that is almost entirely orange; front of head orange, extremity of legs yellow (*Photo*). This coloration corresponds to the variant *nigrithorax* du Buysson. While preying on a diverse range of insects, Asian yellow-legged hornet shows a strong preference for honeybees, waiting in flight for workers in front of hives. The large nest, often hooked high in tree tops, may contain several thousand individuals (*see Figure 12.11 in Chapter 11*). The colony founded in April always dies before the end of the year. Future founder queens only survive and overwinter in bark or ground shelters. Their long-distance dispersal is then possible through agricultural and forestry trade movements. The young queen flight capability is not yet assessed, but in general, a hornet adult is able to fly up to 2 km from its nest.

Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range: Mostly depends on the presence of high trees or buildings for nesting: X25- Domestic gardens of villages and urban peripheries; X10- Mixed landscapes with a woodland element ("bocages"); G- Woodland and forest habitats and other wooded land.

Native range: Temperate Asia, probably from Yunnan (south-west China).

Invaded range. Introduced in southwestern France (Lot-et-Garonne département) before 2004. Since then, has widely expanded in other parts of France (*Map left*). The invasion development has been annually traced (*Map right*).

Pathways: Probably through international horticulture trade.

Credit: Jean Haxaire

Impact and management: As honeybees are its main prey, the Asian hornet represents a new threat to European beekeeping. It also feeds on ripe fruits, and may thus have detrimental effects on local fruit crops. However, economic impact needs to be accurately assessed. A significant public concern also exists because of the sting risk related to the increasing abundance of nests in invaded urban territories. Ecosystem impact includes threat to biodiversity due to the huge predatory pressure on insects (mainly pollinators), as well as potential side-effects on non target species as a consequence of uncontrolled mass trapping and colony destruction by beekeepers and general public. Traps and poisoned baits kill numerous other insects, notably the common yellow-jackets and the European hornet, while nests filled with insecticides and left on the spot threaten birds that fed intensively on brood of poisoned colonies. Nest distribution in France is mapped each year within the program *Inventaire National du Patrimoine Naturel* website (MNHN, Paris). Chemical control: mass destruction of founder queens in spring seems to have virtually no effect; the best control measure is to kill off a colony by spraying cypermethrine inside the nest after dark, when foraging activities have ceased. The nest is then removed and burnt. However, nests are often difficult to locate before leaf fall, when sexual progeny is already produced. The use of specific baited mass traps to protect hives is under investigation.

Selected references

Haxaire J, Bouquet JP, Tamisier JP (2006) *Vespa velutina* Lepeletier, 1836, une redoutable nouveauté pour la Faune de France (Hym., Vespidae). Bulletin de la Société entomologique de France 111: 194.

Villemant C, Haxaire J, Streito JC (2006) Premier bilan de l'invasion de *Vespa velutina* Lepeletier en France (Hymenoptera, Vespidae). Bulletin de la Société entomologique de France 111: 535–538.

14.63 – *Reticulitermes flavipes* (Kollar, 1837) - Eastern subterranean termite (Isoptera, Rhinotermitidae)

Marc Kenis

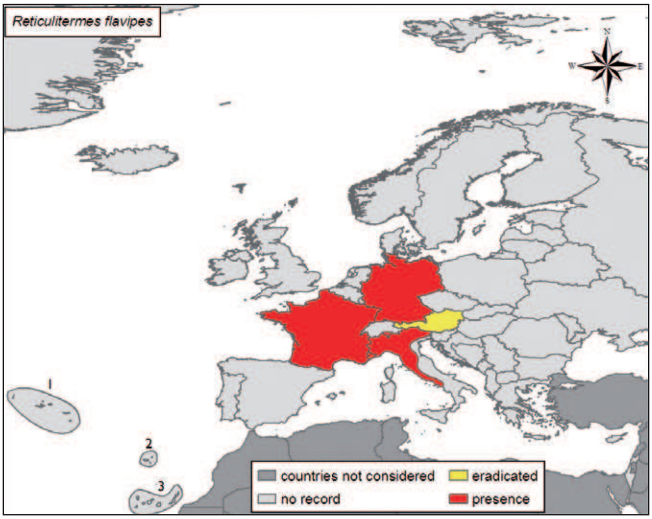
Description and biological cycle: The genus *Reticulitermes* is represented by several species in Europe, America and Asia. A complex of closely related species with uncertain taxonomic status occurs in southern Europe. One species, *R. flavipes*, is of North American origin and has been introduced into Western France, where it had been first described as *R. santonensis* de Feytaud and subsequently synonymised with *R. flavipes*. The same species has also been accidentally introduced in some cities in Germany and Austria. In France, *R. flavipes* is expanding its range further north. In common with all termites, *Reticulitermes* spp. are social, living in colonies in the soil. These colonies contain various castes: workers, soldiers, alate reproductives and replacement reproductives. The latter are particularly numerous in *Reticulitermes* spp. and allow the species to build up colonies of millions of individuals. Nests are built in the ground, usually in a humid environment. Workers bore into wood in contact with the ground to feed the colony (*Photo*). Dry wood (e.g. building structures) as well as living trees or other sources of cellulose can be attacked.

Native habitat (EUNIS code): G1- Broadleaved deciduous woodlands; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; J- Constructed, industrial and other artificial habitats.

Habitat occupied in invaded range (EUNIS code): G1 Broadleaved deciduous woodlands, I: Regularly or recently cultivated agricultural, horticultural and domestic habitats, J: Constructed, industrial and other artificial habitats.

Native range: North America.

Credit: Gary Alpert, Harvard University, www.insectimages.org



Introduced range: France, Germany and Austria (*Map*).

Pathways: Unknown.

Impact and management: *Reticulitermes flavipes* is particularly harmful to wooden elements in buildings but can also attack living trees, as observed with street trees in Paris recently. *Reticultermes* spp. have had huge economic impacts worldwide. In the USA, subterranean termites are believed to cause more than US$2 billion in damage each year. In France, the recent spread of *R. flavipes* and Southern European species has caused major concern. New regulations were therefore set up to limit the spread. In nature, indigenous termites are beneficial, by recycling dead trees and other wood material. The impact of *Reticulitermes* spp. on the soil fauna and flora in newly invaded areas in Europe has not been studied. Management options are numerous and include both prevention and control methods. Building chemical or physical barriers can achieve prevention before and after construction (e.g. chemical wood treatment or steel mesh). Preventing moisture in the soil and in construction structures is an alternative strategy. Curative methods include termiticide injections, baits, trapping methods, etc.

Selected references

Szalanski AL, Scheffrahn RH, Messenger MT, Dronnet S, Bagnères AG (2005) Genetic evidence for the synonymy of two *Reticulitermes* species: *Reticulitermes flavipes* and *Reticulitermes santonensis*. Annals of the Entomological Society of America 98: 395–401.

Clément JL, Bagnères AG, Uva P, Wilfert l, Quintana A, Reinhard J, Dronnet S (2001) Biosystematics of *Reticulitermes* termites in Europe: morphological, chemical and molecular data. Insectes Sociaux 48: 202–215.

Pearce MJ (1997) *Termites*. Biology and Pest management. Wallingford, UK: CAB Intenational. 172 pp.

14.64 – *Hyphantria cunea* Drury - Fall webworm (Lepidoptera, Arctiidae)

Ferenc Lakatos

Description and biological cycle: Large white moth species with a wingspan of 19–30mm (*Photo left- see also Figure 11.6k- adult male and 11.6i- adult female in Chapter 11*). Immature larvae feed gregariously, forming large webs on tree branches (*Photo right*). Mature larvae tend to be solitary feeders and consume the entire leaf leaving only the petiole. Highly polyphagous, with over 200 known host species including *Acer negundo*, *Morus* spp., *Prunus* spp., *Malus* spp. and even *Populus* and *Quercus*. Adults show remarkable dispersal powers. In Europe, there are up to three generations per year. In Japan, recent climate change has resulted in a shift from a bivoltine to a trivoltine life-cycle in at least a part of the range, together with significant changes in the length of the critical photoperiod for diapause induction. Overwinters as pupae. Adults emerge from mid April onwards and females lay 500 (spring generation) to 800 (summer generations) eggs, usually towards the top part of the host tree. Larvae produce 5–7 instars, feeding gregariously in a light web, except the first and last instars. Larval development takes 24–57 days, depending on climate and host nutrition conditions.

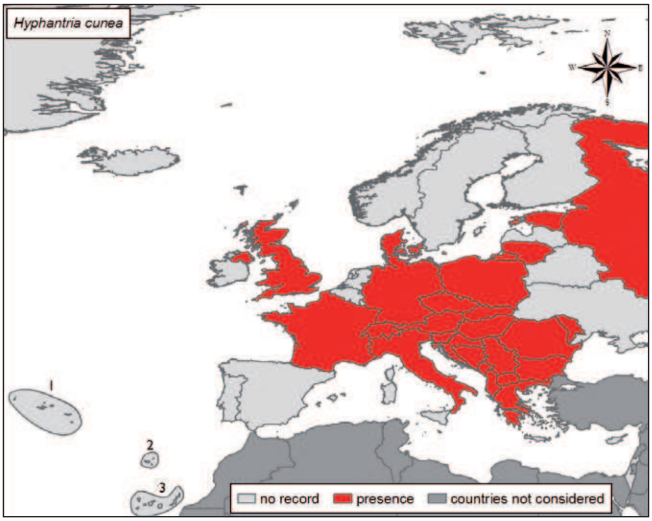
Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; G5- Lines of trees.

Native range: North America.

Introduced range: Two known introductions, the first one to Hungary during WW II (first individual found in 1940 in Budapest) and the second one in 1978 in Bordeaux, France.


Credit: Zdenek Laštůvka



Nowadays, present in most of Europe, except UK, Scandinavia and Iberian Peninsula (*Map*).; also introduced to Japan and China.

Pathways: Probably trade of ornamental trees.

Impact and management: Threat to orchards, ornamentals and forest trees in some regions of Central and Eastern Europe, as well as in Eastern Asia. Particularly damaging to ornamentals; however, severe damage has occurred only during the expansion phase after establishment. It was a serious pest in Bulgaria, Romania, Hungary, former Yugoslavia, Russia and northern Italy. Nowadays frequent along roadsides, urban forests, parks and gardens. Constantly present in orchards, where the usual plant protection practices keep the population low. Heavy feeding by the caterpillars over time can lead to defoliation (leaf loss) and limb and branch die-back. Trees/plants are often totally defoliated by late-instar larvae, particularly in the second generation. Environmental impacts are likely, given the high polyphagy and impact on individual plants. Natural enemies have already adapted to the species as well (e.g. *Trichogramma*, *Tachina* and Chalcidoidea, and even birds). Previously both mechanical (elimination of webs) and chemical (insecticide) controls were widely used, but nowadays, biological control (at least in the native habitats) plays a much more important role.

Selected references

Gomi T, Nagasaka M, Fukuda T, Hagihara H (2007). Shifting of the life cycle and life-history traits of the fall webworm in relation to climate change. *Entomologia Experimentalis and Applicata* 125: 179–84.

Rezbanyai-Reser L (1991) *Hyphantria cunea* Drury, 1773, und *Noctua tirrenica* Biebinger, Speidel & Hanigk, 1983, im Südtessin, neu für die Schweiz (Lep.: Arctiidae, Noctuidae). *Entomologische Berichte Luzern* 26: 94–96, 135–152.

Torp R (1987) Ny dansk spinder: *Hyphantria cunea* Drury f. textor Harr. *Lepidoptera* 5: 83–86.

14.65 – *Paysandisia archon* (Burmeister, 1879) - The castniid palm borer (Lepidoptera, Castniidae)

Carlos Lopez-Vaamonde & David Lees

Description and biological cycle: Large dayflying moth with clubbed antennae, wingspan 75–120 mm, upperside forewing greenish brown in both sexes, hindwing bright orange with a black band postdiscal to white spots (*Photo left*). Forewing underside orange, excepting beige tips. Upright fusiform eggs, about 4.7 mm. long and 1.5 mm wide, laid by the female's extensible ovipositor between mid-June and mid-October. Fertile eggs pink, laid among palm crown fibres, at the base of leaf rachis. Larvae hatch after 12–21 d, whitish and grub-like, up to 9 cm long, endophytic cannibals, forming galleries 20–30 cm long inside palm trunks, towards the crown (*Photo right*). 7–9 larval instars, overwintering as larva, in a false cocoon. Pupation occurs at the rachis base or between inflorescences, where larvae form a cryptic cocoon of palm fibres, pupating for 43–66 d. Pupae remain attached to the cocoon after adult emergence. Adults observed from mid May to late September, males especially exhibiting powerful territorial flight in hot sunshine. Males live about 24 d and females about 14 d. One generation per year (sometimes bivoltine) in Mediterranean locations. Larvae can live > 18 months and overall life cycle 13–22 months, exceptionally three years. Castniid palm borer infests a wide range of palm genera including *Chamaerops*, *Latania*, *Livistona chinensis*, *Phoenix canariensis*, *Syagrus* spp., *Trithrinax campestris* (probable import host), in the native area. Reported from *Brahea*, *Butia*, *Chamaerops*, *Livistona* spp. *Phoenix* spp., *Sabal*, *Trachycarpus*, *Trithrinax campestris* and *Washingtonia*, in the introduced area.

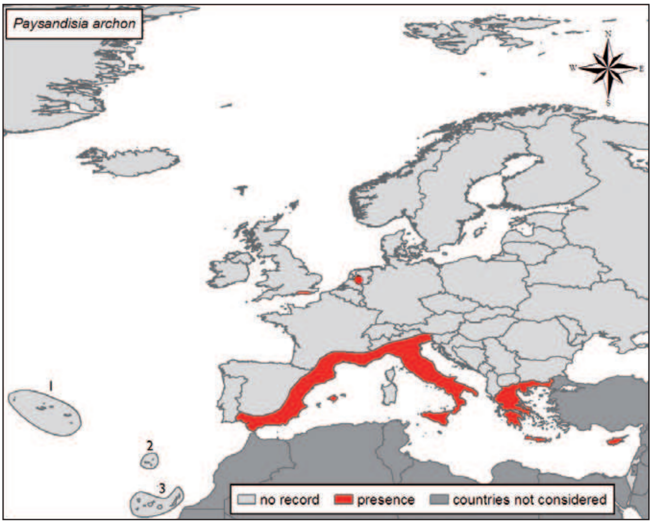
Native habitat (EUNIS code): G2 - Broadleaved evergreen woodland.

Habitat occupied in invaded range (EUNIS code): I2- Cultivated areas of gardens and parks; X24 Domestic gardens of city and town centres; J100- Greenhouses.

Native range: Neotropical region: western Uruguay, northwest Argentina, Paraguay and southeastern Brasil.

Introduced range: First introduced with its foodplant to Spain and France in the 1990's, well established by 2001 when first reported from Catalonia in Northeastern Spain. Rapidly spread

Credit: Laurence Olivier



to coastal areas of the other Mediterranean regions where palms are widely used as ornamentals. Now common and widespread in Spain (along the Mediterranean coast from Girona to Alicante and the Balearic islands) southeastern France (Var and Hérault), Italy (Campania, Lazio, Toscana, Marche and Sicily), and in Greece mainland and Crete); also introduced in England (Sussex, one example in 2002) and Netherlands (one example in 2006) (*Map*). Spreading tendency.

Pathways: Introduced with trade of palm trees as ornamentals**.**

Impact and management: Pest species in parks and palm nurseries, causing severe damage (such as holes in leaves and deformation) and death of plants. Conservation concern exists for the native Mediterranean Fan Palm, *Chamaerops humilis*; numerous larvae may be found in one plant. Biological control in Europe is not yet achieved. As last resort, palms can be pulled up and burned. Chemical control of this species is also difficult since larvae are endophytes. Best control has been obtained by wetting crown and trunk with contact or systemic organophosphorus insecticides (Chlorpyrifos, Acephate and Dimethoate). Ostrinil (*Beauveria bassiana*147 strain) biological insectides normally used for the European Corn Borer cause egg and up to 80% larval mortality for crown treatment every two weeks during flight season, and can be used as a curative. Trials done with“glue” used as physical barrier (both preventing adult females from ovipositing and developing adults from emerging) have had positive results.

Selected references

Colazza S, Privitera S, Campo G, Peri E, Riolo P (2005) *Paysandisia archon* (Lepidoptera: Castniidae) a new record for Sicily. L'Informatore Fitopatologico 5: 56–57.

Hollingsworth T (2004) Status of *Paysandisia archon* (Burmeister) (Lepidoptera: Castniidae) in southern Europe. British Journal of Entomology and Natural History 17: 33–34.

Sarto i Monteys V (2002) The discovery, description and taxonomy of *Paysandisia archon* (Burmeister, 1880), a castniid species recently found in southwestern Europe (Castniidae). Nota Lepidopterologica 25: 3–16.

14.66 – *Diplopseustis perieresalis* (Walker, 1859) - The exotic pyraloid moth (Lepidoptera, Crambidae)

Jurate De Prins & Willy De Prins

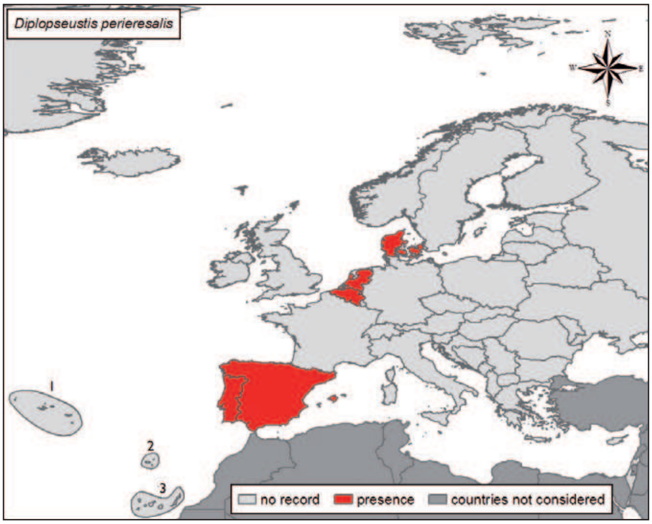
Description and biological cycle: Small moth, wingspan 12–14 mm, forewing greyish with some whitish transverse lines, indicated by separate dots; submarginal line more conspicuous; in some specimens, darker greyish antemedian transverse line, most visible towards inner margin (*Photo*). *Termen** sinuous. Labial palps *porrect**, a little longer than eye diameter. Hindwings whitish with greyish suffusion, dark marking in anal corner, transversed by white line parallel to wing margin. Biology undescribed, but larva supposed to live on *Carex* spp. Probably hibernating in larval stage.

Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): E3 - Seasonally wet and wet grasslands.

Native range: Oriental and Australasian regions: Australia, Brunei, China (coastal regions), Fiji, Hong Kong, India, Indonesia, Japan, Malaysia (Borneo, Sarawak), New Zealand, Taiwan.

Credit: C. van den Berg



Introduced range: First recorded from Portugal in 2000. Then observed in several countries of western and Southern Europe: Belgium, Netherlands, Portugal, Spain (mainland, Balearic and Canary islands), United Kingdom (Scilly Islands) (*Map*).

Pathways: Long-distance dispersal probably human-mediated (plant trade between Australia, New Zealand, and Japan, and the Canary Islands), although the species has a strong dispersal power and could spread on its own. Spreading mode within Europe unknown.

Impact and management: Infestation rate still very low, no economic damage (*Carex* spp. are not commercially valuable). Neither chemical nor biological measurements necessary.

Selected references

Mackay A, Fray R (2002) *Diplopseustis periersalis* [sic] (Walker) on Tresco, Isles of Scilly – the first record for Britain and the western Palearctic region. Atropos 16: 26.

Speidel W, Nieukerken van EJ, Honey MR, Koster SJC (2007) The exotic pyraloid moth *Diplopseustis perieresalis* (Walker) in the west Palaearctic region (Crambidae, Spilomelinae). Nota Lepidopterologica 29: 185–192.

14.67 – *Phthorimaea operculella* (Zeller, 1873) - Potato tuber moth (Lepidoptera, Gelechiidae)

Georgyi Trenchev and Katia Trencheva

Description and biological cycle: Adult small, light grey moth, about 10 mm long with wing-span of about 12 mm (*Photo left- adult on potato*). Greyish-brown wings patterned with small, dark specks. Larvae light brown with a brown head. Mature larvae reach 15–20 mm long, pink or greenish. Multivoltine, developing four or more generations per year, depending on climate conditions. In field conditions, adult, larva or pupa overwinters under crop residues in the upper layer of ground. In temperate climates, overwintering occurs mainly in storehouses. Adult moth emerges in spring, and found until the end of October. Moths are active after sunset. They lay eggs in groups of 2–3 or individually on the lower sides of plant leaves, sometimes on leafstalks, stems, exposed potato tubers, lumps of soil in the field, on potato tuber buds and on bags in storehouses. Female fecundity is 150–200 eggs. Embryonic development lasts 3–10 days. Larval development lasts for 11–14 days and passes through four instars. Pupal stage lasts 6–8 d. In storehouses, the pest develops continuously throughout the year.

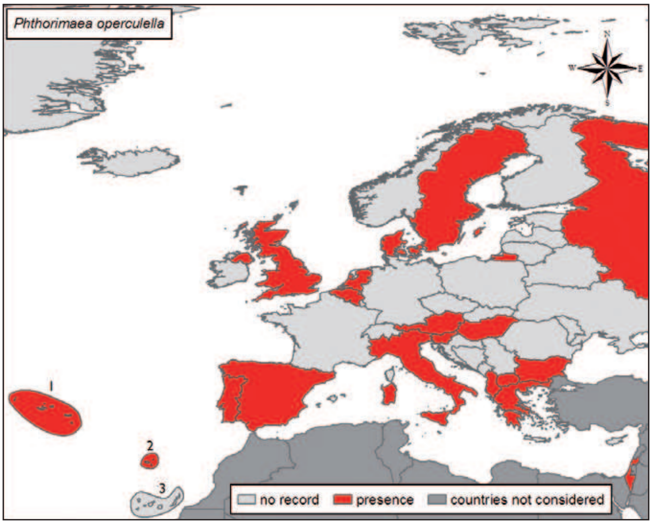
Native habitat (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2-Cultivated areas of gardens and parks; J100- glasshouses.

Native range: Probably originates from South America.

Introduced range: Widely distributed worldwide, recorded in more than 70 countries. Known in Europe since the beginning of the 20th century, where it is mainly found in potato fields and storehouses (*Map*).

Credit: Katia Trencheva



Pathways: Adults fly to potato fields over short distances and they can transported by wind. Over long distances, transportation occurs with infested tubers and re-infestation of fields then occurs from potato storehouses.

Impact and management: Damage is most frequent on stored tubers after the spring growing season and on young plants in the autumn growing season. Larvae bore holes and galleries in the tubers (*Photo right*). Larval penetration holes are unsightly and induce soft rot. *Phthorimaea operculella* can be a very serious potato pest, especially in tropical and sub-tropical regions, including the Mediterranean region. The attack results in lowered market value and quality of the infested tubers. Infestation may start early in the field, up to 15 d before tuber maturity. By harvest time, a substantial number of tubers may already be infested. This harvest-time infestation is responsible for the further development of infestation in stores. Integrated pest management methods have been developed in various parts of the world. Control measures include the use of pesticides; cultural practices include use of healthy tubers, irrigation or early harvest. Biological control is achieved through the introduction of parasitoids but also the use of Bt or Baculovirus, and through use of resistant varieties. Pheromones can be used both for monitoring and for control trapping in storage.

Selected references

CABI (2007) Crop Protection Compendium. CD-ROM. CAB International, Wallingford, UK.

Das GP, Magallona ED, Raman KV, Adalla CB, 1992. Effects of different components of IPM in the management of the potato tuber moth, in storage. Agriculture, Ecosystems & Environment 41: 321–325.

Trivedi TP, Rajagopal D, 1992. Distribution, biology, ecology and management of potato tuber moth, *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae): a review. Tropical Pest Management, 38: 279–285.

14.68 – *Cameraria ohridella* Deschka & Dimić, 1986 - Horse chestnut leaf-miner (Lepidoptera, Gracillariidae)

Sylvie Augustin

Description and biological cycle: Tiny moth, 3–5mm long, forewing background orange-brown with basal white longitudinal streak and white v-marks bent towards costa and running straight across dorsum at rest, edged posteriorly in black, two of these fasciae continuous medially, one post-medial fascia interrupted and a final convex fascia towards wing apex, bisected by a diffuse blackish subapical streak (*Photo left- see also Figure 11.7c in Chapter 11*). Fringe forming a conspicuous orange tuft that is longest dorsally at rest. Head tufted with orange hair-like scales intermixed with white, scape and base of antenna silvery white. Antennae about 4/5 forewing length. Phytophagous larvae, mining leaves of white-flowered horse chestnut *Aesculus hippocastanum*; but can also develop on other *Aesculus* species and occasionally on maples, *Acer pseudoplatanus* and *A. platanoides*. Leaf mines from April onwards; an average of 75 eggs are laid per female on the upper epidermis of horse-chestnut leaves. Produces four (rarely five) mining and two spinning larval instars; usually three generations per year in W Europe, but up to five overlapping generations depending on weather conditions and climate. Pupae diapause in leaves.

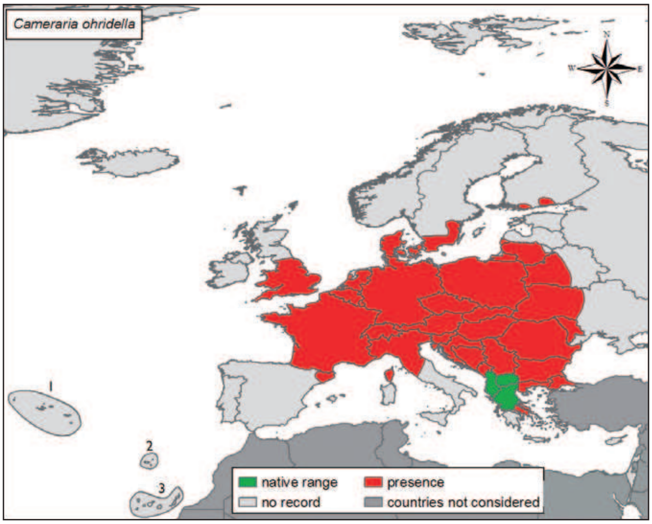
Native habitat (EUNIS code): G1 - Broadleaved deciduous woodland.

Habitat occupied in invaded range (EUNIS code): G1 - Broadleaved deciduous woodland; I2 - Cultivated areas of gardens and parks; X13 - Land sparsely wooded with broadleaved deciduous trees; X11 - Large parks; J - Constructed, industrial and other artificial habitats.

Native range: Southern Balkans.

Introduced range: Most of Europe, except part of Northern Europe and Western Russia (*Map*). Increasing its distributional range and abundance in newly colonized areas.

Credit: Sylvie Augustin



Pathways: Adult moths are transported by wind. Anthropogenic transport occurs by vehicles, in infested leaf fragments or infested nursery stock.

Impact and management: Severely defoliated trees produce smaller seeds with a lower fitness that affects tree regeneration and seriously impairs recruitment of horse chestnut in the last endemic forests in the Balkans. A single leaf can host up to 106 leaf-miners (*Photo right*). Parasitism rates low, as most parasitoids emerge when larvae or pupae are not yet available; this may have an important impact on native leaf-miners. There is significant public concern because of aesthetic impact. Main costs are caused by by removal or replacement of severely damaged horse chestnut trees planted in cities and villages. Complete removal of leaf litter, in which pupae hibernate, is the only effective measure available to lessen damage. The majority of adults can be prevented from emerging when leaves are properly composted (e.g., mulching of horse chestnut leaves with a layer of soil or uninfested plant material). Chemical control: aerial spraying with dimilin is efficient; spraying with Fenoxycarb combined with a surfactant has proved effective. Other "biological pesticides" with fewer non-target effects, such as neem, are also feasible, but their efficiency is considered to be lower. Stem injection is also efficient, but is not widely registered. This injures trees through necrosis and infections, and systemic insecticide may cause side effects on non-target species such as honey bees.

Selected references

Gilbert M, Grégoire J-C, Freise J, Heitland W (2004) Long-distance dispersal and human population density allow the prediction of invasive patterns in the horse-chestnut leafminer *Cameraria ohridella*. *Journal of Applied Ecology* 73: 459–468.

Lees DC, Lopez-Vaamonde C, Augustin S (2009) *Cameraria ohridella* Deschka & Dimić 1986. http://eolspecies.lifedesks.org/pages/8675.

Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mena NM, Magnoux E Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive horse-chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). *Molecular Ecology* 18: 3458–3470.

14.69 – *Parectopa robiniella* (Clemens, 1863) - Locust Digitate Leafminer (Lepidoptera, Gracillariidae)

David Lees

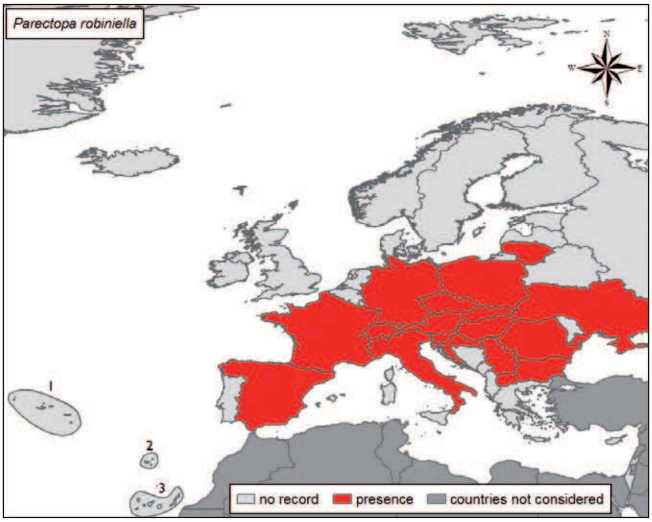
Description and biological cycle: Small moth, wingspan 5.73–7.26 mm. Forewing background dark orange with four white curved flecks outlined in fuscous, running from costa and tergal edge of forewing in an interdigitate fashion towards middle of wing; white costal mark in between most apical flecks. Hindwing mid brownish with brownish cilia tipped apically in white (*see Figure 11.6b in Chapter 11*). Hindlegs conspicuously banded brown and white. Mine starts close to base of leaf with egg laid on underside, at the base of a fork made by the veins, where the larva bores through to upperside and forms a distinctive whitish digitate shape, straddling the midrib (*Photo*), unlike *Phyllonorycter robiniella*, which may precede it by about two weeks, and in U.S.A., *Chrysaster ostensackenella* Fitch. Larva greenish and solitary, leaf-miner on Black Locust (or False Acacia) trees *Robinia pseudacacia* and *R. hispida*, and on other Fabaceae including *Amorpha fruticosa*, *Galactia volubilis* and *Desmodium* sp. Leaf-mines and adult flight occurs from June to October (in two, sometimes overlapping, generations). Larva pupates in leaf litter on ground, in contrast to *Phyllonorycter robiniella*, and probably thus less susceptible to parasitism.

Native habitat (EUNIS code): G- Woodland, forest and other wooded land.

Habitat occupied in invaded range (EUNIS code): G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; I2- Cultivated areas of gardens and parks; X24- Domestic gardens of city and town centres.

Native range: North America (Canada: Québec), U.S.A. (Florida, Kentucky, Maine, Maryland, Michigan, Missouri, New Orleans, New York, Pennsylvania, Vermont, Wisconsin)

Credit: György Csóka



Introduced range: First observed in Europe in Italy in 1970, Locust Digitate Leafminer has spread relatively quickly in various directions to Western and Central Europe and to the Balkans (*Map*).

Pathways: Unknown, possibly via plant trade.

Impact and management: Causes damage to false acacia trees including leaf drop as early as June in cases of severe infestation. Potential impact on ornamental trees and industrial plantations. Natural control includes at least 20 species of wasps in Braconidae (*Pholetesor circumscriptus*, *P. nanus*), Chalcidoidea Encyrtidae (*Ageniaspis* sp.), Eupelmidae (*Eupelmus urozonusi*), Eulophidae (*Achrysocharoides cilla*, *Astichus trifasciatipennis*, *Chrysocharis nitetis*, *Cirrospilus viticola*, *Closterocerus cinctipennis*, *C. formosus, C. trifasciatus*, *Elachertus inunctus*, *Holcothorax testaceipes*, *Hyssopus benefactor*, *Minotetrastichus frontalis*, *Neochrysocharis formosa, Pediobius saulius*, *Pnigalio pectinicornis*, *P. soemius*, *Sympiesis acalle*, *S. marylandensis*, *S. sericeicornis* and Ichneumonidae (*Gelis acarorum*, *Diadegma* sp.), but parasitism levels may be too low to have much impact. As for *Phyllonorycter robiniella*, parasitoids have easily shifted from other hosts, but this species has been less susceptible.

Selected references

Ivinskis P, Rimsaite J (2008) Records of *Phyllonorycter robiniella* (Clemens, 1859) and *Parectopa robiniella* Clemens, 1863 (Lepidoptera, Gracillariidae) in Lithuania. *Acta Zoologica Lituanica* 18: 130–133.

Lakatos F, Kovács Z, Stauffer C, Kenis M, Tomov R, Davis DR (2003) The Genetic Background of Three Introduced Leaf Miner Moth Species - *Parectopa robiniella* Clemens 1863, *Phyllonorycter robiniella* Clemens 1859 and *Cameraria ohridella* Deschka et Dimic 1986. In: Proceedings: IUFRO Kanazawa (2003) "Forest Insect Population Dynamics and Host Influences", 67–71.

14.70 – *Phyllonorycter issikii* (Kumata, 1963) (Lepidoptera, Gracillariidae)

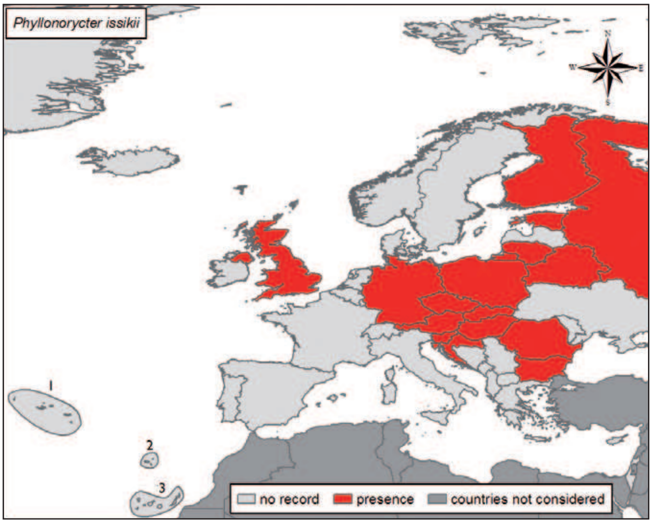
David Lees

Description and biological cycle: Small moth, wingspan 7.0–7.5 mm. Thorax and forewing ground colour golden to light brownish ochreous, with blackish stripes and three white stripes in summer form (*see Figure 11.6d in Chapter 11*), dusted with white scales in autumn form (*see Figure 11.6c in Chapter 11*), well camouflaged for hibernation; hindwings pale grey, cilia tinged with yellow. Adult resembles *Phyllonorycter corylifoliella*, but male genitalia highly asymmetric, right valve especially wide and left one slender. Eggs oblong, greenish, about 0.24 x 0.35 mm. Larva yellowish towards caudal end and white toward head. Leaf-miner on lower surface (*Photo*) of small-leaved Lime *Tilia cordata*, *Tilia platyphyllos* or various crosses such as *Tilia* x *vulgaris* (Tiliaceae), with adults flying in two generations at end of April and May and August-September (in Europe). Oligophagous on *Tilia*, apparently without strong preference. Feeds on *T. maximowicziana*, *T. kiusiana* and *T. japonica* (in Japan), *T. amurensis* (far eastern Russia) and *T. mandshurica* (in Korea). Development: egg, 4–8 d, larva in five instars, the last two tissue feeding, 13–40 d, pupa 10–15 d. Prefers trees in understory/shade. Mine when unfolded showing micro-ridges, elliptical to oblong, whitish, on underside of leaf, usually at fork of primary or secondary veins, with frass piled up at one end. Hibernates as adult.

Native habitat (EUNIS code): G - Woodland, forest and other wooded land.

Habitat occupied in invaded range (EUNIS code): G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I - Regularly or recently cultivated agricultural, horticultural and domestic habitats; I2 - Cultivated areas of gardens and parks; X24 - Domestic gardens of city and town centres. Spreading quite rapidly westwards especially after 2000.

Credit: Hana Šefrová



Native range: Japan (Hokkaidō, Honshũ, Kyũshũ) and probably also in far eastern Russia eastern China and Korea (where first reported 1977).

Introduced range: First reported from Moscow in 1985, *Phyllonorycter issikii* spread to the Baltic countries of the Baltic countries and most of Central Europe (*Map* and Šefrová (2002) for a review of spread in Europe).

Pathways: Apparently spread by wind and possibly also by horticultural trade and passive spread of hibernating adults, since the distance between eastern and western Russia seems too large for possible long distance aerial transport.

Impact and management: Causes damage including limited leaf folding to lime trees. Potential aesthetic impact to park and garden trees is relatively minor, since sunny branches are avoided, and no native *Tilia* populations are threatened. Natural controls include the chalcidoid eulophid wasp parasitoids *Chrysocharis laomedon*, *Mischotetrastichus petiolatus*, *Pediobius saulius*, *Pleuroppopsis japonica*, *Sympiesis laevifrons* and *S. sericeicornis*, but biological control seems unnecessary, since parasitoid levels attained 20% in some localities even the year after arrival in eastern Europe.

Selected references

Ermolaev IV, Motoshkova NV (2008) Biological invasion of the Lime Leafminer Lithocolletis issikii Kumata (Lepidoptera, Gracillariidae): interaction if the moth with the host plant. Entomological Review, 88: 1–9.

Noreika R (1998) *Phyllonorycter issikii* (Kumata) (Lepidoptera, Gracillariidae) in Lithuania. Acta Zoologica Lituanica 8: 34–37.

Šefrová H (2002) *Phyllonorycter issikii* (Kumata, 1963) - bionomics, ecological impact and spread in Europe (Lepidoptera, Gracillariidae). Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 50: 99–104.

14.71 – *Phyllonorycter platani* (Staudinger, 1870) (Lepidoptera, Gracillariidae)

David Lees

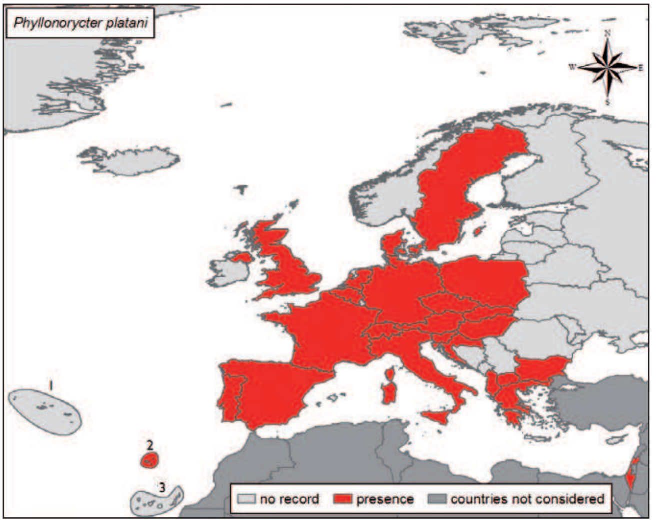
Description and biological cycle: Small moth, wingspan 8–10 mm. Adult forewing light golden-orange, with silvery white markings: mediobasal stripe to a third of forewing length, longer white stripes running along costa and tergum; narrow transverse medial band at 2/3 that may be divided; apically two costal and two dorsal streaks that may meet in middle of wing and are basal to a small black apical eyespot (*see Figure 11.6f in Chapter 11*). Asymmetric male genitalia, left valve at least twice as broad as right. Larva yellowish white, up to 7 mm long. Leafminer on *Platanus orientalis*, *P. racemosa*, *P. occidentalis*, *P. acerifolia*, *P. hispanica* and commonly in urban areas on *Platanus* x *hispanica* (Platanaceae) ("London Plane"). Mine a large distinctive blotch commencing in a sinuous pattern, usually on underside of leaf, between veins, appears brownish underneath, mottled upperside, and semi-transparent against sky (*Photo left- mine on Platanus leaf; Photo right- mine opened to show third- instar larva*). Pupa light brown, pupates in a whitish cocoon within leaf on ground. Adults on wing between April and September, in two generations, with larvae of summer generation diapausing.

Native habitat (EUNIS code): Unknown

Habitat occupied in invaded range (EUNIS code): G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice; I - Regularly or recently cultivated agricultural, horticultural and domestic habitats; I2 - Cultivated areas of gardens and parks; X24 - Domestic gardens of city and town centres.

Native range: Unknown, but possibly Balkans; described from Italy.

Credit: Hana Šefrová



Introduced range: Recorded in most European countries wherever *Platanus* trees have been planted (*Map* and Šefrová (2001) for a review of its dispersal history in Europe). Also introduced in central Asia (Kazakhstan, Tajikistan, Turkmenisatn), Asia Minor (Iran, Syria), and apparently in the USA (California).

Pathways: Passive dispersal via fallen leaves has greatly facilitated the rapid spread of *Phyllonorycter platani*.

Impact and management: Causes damage to plane trees, rarely unsightly, as leaves remain green, but sometimes reaching a density of 60 mines per leaf. Therefore of potential, but not usually severe, aesthetic impact. Leaves can be gathered up and burned. Chemical control not recommended nor necessary. Natural control by parasitoid wasps: at least 57 spp. recorded, including families Braconidae (genera *Apanteles*, *Colstus*, *Pholeteor*), Chalcididae (*Conura*), Encyrtidae (*Ageniaspis*); Eulophidae (*Achrysocharoides*, *Aprostocetus*,*Chrysocharis*, *Cirrospilus*, *Clostocerus*, *Diglyphus*, *Elachertus*, *Eulophus*, *Horismenus*, *Minotetrastichus*, *Pediobius*, *Pnigalio*, *Sympiesis*); Ichneumonidae (*Itoplectis*, *Pimpla*, *Scambus*, *Triclistus*); Pteromalidae: *Chlorocytus*, *Conomorium*, *Pteromalus*); Torymidae (*Torymus*).

Selected references

Frankenhuyzen Av (1983) *Phyllonorycter platani* (Staudinger, 1870) (Lep.: Gracillariidae), een bladmineerder op plataan in Nederland. Entomologische Berichten 43: 19–25.

Šefrová H (2001) *Phyllonorycter platani* (Staudinger) - a review of its dispersal history in Europe (Lepidoptera, Gracillariidae). Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 49: 71–75.

14.72 – *Phyllonorycter robiniella* (Clemens, 1859) (Lepidoptera, Gracillariidae)

David Lees

Description and biological cycle: Small moth, wingspan 5.98–6.37 mm. Adult forewings light orange with four silvery-white diagonal striae running from costa towards tergal edge, but reflexed at middle of wing, at least the terminal one divided, apically a black eyespot; base of wings silvery white (*see Figure 11.6g in Chapter 11*). Larva in Europe a leaf-miner of *Robinia pseudacacia* (Fabaceae) (in North America using also *R. hispida*, *R.viscosa* and *R. neomexicana*, but not recorded on other genera), from June to October, in two or usually three generations from June to October in Europe. Diaphanous whitish, tentiform blotch mine that does not traverse midrib, but may occupy a large part of one side of the leaf, usually on underside (*Photo*), occasionally on leaf upperside, and which may sometimes merge to contain up to 15 larvae. Egg, light greenish grey, 6–10 d, larva, hypermetamorphic, in final two of five tissue-feeding instars, cylindrical, 20–50 d, pupa in oval white cocoon within the mine 7–20 d, 5–11 weeks for development. Hibernates as adult.

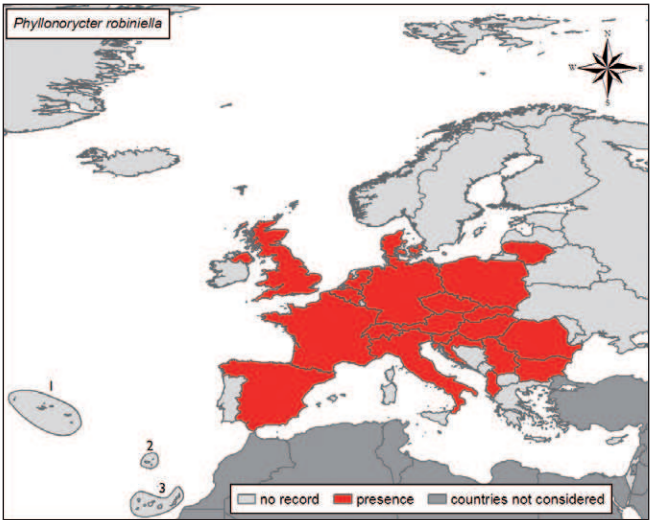
Native habitat (EUNIS code): G - Woodland, forest and other wooded land.

Habitat occupied in invaded range (EUNIS code): I - Regularly or recently cultivated agricultural, horticultural and domestic habitats; I2 - Cultivated areas of gardens and parks.

Native range: Nearctic: Eastern and central USA (North America), throughout the native range of *Robinia pseudacacia*, including Canada (Québec), U.S.A (Connecticut, Florida, Illinois, Kentucky, Maine, Maryland, Massachusets, Michigan, New York, Texas, Vermont, and Wisconsin).

Introduced range: First recorded in Europe in 1983 in Switzerland, it then invaded most of Western, Central and Northern Europe: Austria, Belgium (from 2000), Croatia, Czech Republic, France, Germany, Hungary, Italy (1988), The Netherlands (1999), Poland, Slovakia, Spain (Barcelona 2000), Switzerland (1983), Ukraine. Apparently spreading faster eastwards than westwards (*Map*).

Credit: Hana Šefrová



Pathways: Passive wind dispersal may be unusually important for this species, as although leaves can be carried by cars, pupae hatch before leaf fall, making leaf transport more more unlikely than for some other gracillariid species.

Impact and management: Causes premature leaf drop to false acacia trees and thus has potential aesthetic and physiological impact. Reported to have a higher surface area impact on industrial plantations than *Parectopa robiniella*. Damage must be weighed against considerations that false acacia is itself an undesirable alien in some European ecosystems. Chitin synthesis inhibitors applied in late May could cure leaf drop. Natural control includes at least 22 species of (polyphagous) braconid (*Apanteles nanus*, *Colastes braconius*, *Pholetesor bicolor*, *P. circumscriptus*, *P. ornigis*), and chalcidoid eupelmid and eulophid wasps (*Achrysocharoides cilla*, *A. gahani*, *Astichus trifasciatipennis*, *Baryscapus nigroviolaceus*, *Chrysocharis nephereus*, *Closterocerus cinctipennis*, *C. trifasciatus*, *Elachertus inunctus*, *Horismenus fraternus*, *Minotetrastichus frontalis*, *M. platanellus*, *Pediobius liocephalatus*, *P. saulius*, *Pnigalio pectinicornis*, *P. soemius*, *Sympiesis acalle*, *S. marylandensis* and S. *sericeicornis*). Parasitoids have easily shifted from other hosts.

Selected references

De Prins W, Groenen F (2001) *Phyllonorycter robiniella*, een nieuwe soort voor de Belgische fauna (Lepidoptera: Gracillariidae). Phegea 29: 159–160.

Ivinskis P, Rimsaite J (2008) Records of *Phyllonorycter robiniella* (Clemens, 1859) and *Parectopa robiniella* Clemens, 1863 (Lepidoptera, Gracillariidae) in Lithuania. Acta Zoologica Lituanica 18: 130–133.

Šefrová H (2002) *Phyllonorycter robiniella* (Clemens, 1859) - egg, larva, bionomics and its spread in Europe (Lepidoptera, Gracillariidae). Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 50: 7–12.

14.73 – *Cacyreus marshalli* (Butler, 1898) - Geranium bronze (Lepidoptera, Lycaenidae)

Jurate De Prins & Willy De Prins

Description and biological cycle: Small butterfly, wingspan 15–27 mm, upperside forewing brown in both sexes, fringes checkered, hindwing with short tail and conspicuous dark spot close to tail (*Photo left*), upperside thus resembling *Lampides boeticus* (L.). Hindwing fringe pure white with sometimes a narrow, interrupted brown line in the middle. Underside unlikely to be confused with any other European lycaenid. Eggs are laid on the flowers buds or the underside of the leaves of *Pelargonium* spp. Larvae feed mainly on the flowers and flower buds, but also other parts of the foodplant are consumed. First two instars are obligate endophytes in the flower buds, young shoots or leaves; the last three instars are facultative endophytes in all plant tissues, except the roots, but they may also occur as external feeders. Pupation inside the stem or among leaf litter at the base of the foodplant (*Photo right- pupae*). No photoperiod-driven diapause. The species cannot survive severe winters in Central Europe outdoors, but it can complete its life cycle during summer time in this region. Also, it often survives the winter season because geraniums are often put inside at this time, when development is slowed down. Five to six generations per year in Mediterranean locations. Closely associated to *Pelargonium* in the native range.

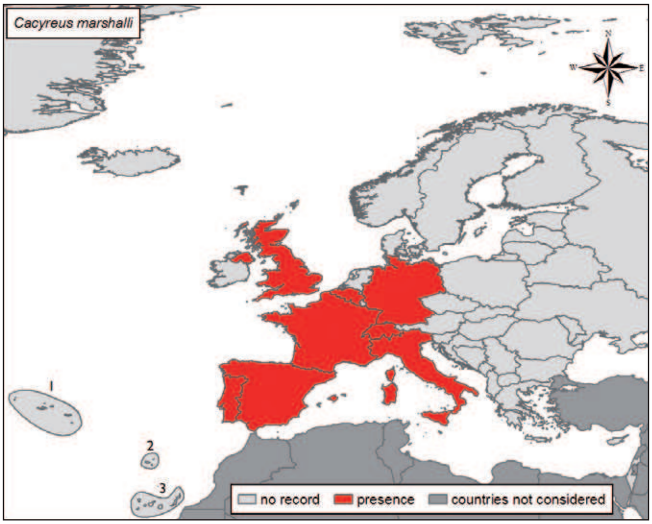
Native habitat (EUNIS code): I2- Cultivated areas of gardens and parks.

Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks.

Native range: Afrotropical region: South Africa.

Introduced range: First introduced with its foodplant to the Balearic Island of Mallorca at the end of the 1980s. Spread fast to the other Balearic islands and the coastal regions of

Credit: Paolo Mazzei



the West-Mediterranean, where geraniums (*Pelargonium* spp.) are widely used as ornamentals. At present common and widely spread in the Mediterranean basin (France common north to Lyon, Italy, Portugal, Spain mainland and Balearic Islands) but rare and isolated records in Central Europe (Belgium, Germany, Netherlands and Switzerland) and United Kingdom (southern coast) (*Map*). Also introduced in Morocco. Spreading tendency.

Pathways: trade of ornamental geraniums (*Pelargonium* spp.)

Impact and management: Pest species in geranium nurseries, causing severe damage and even death of plants. In laboratory conditions, oviposition has been observed on native European *Geranium* species (e.g. *G. pratense*, *G. sylvaticum*), and hence *Cacyreus marshalli* represents a potential threat for both native geraniums and for other *Geranium*-consuming lycaenids, such as *Aricia nicias* (Meigen) and *Eumedonia eumedon* (Esper). Trials with several insecticides on the island of Mallorca had positive results. Since 1995, no autochthonous parasitoids have been reared from *Cacyreus marshalli*.

Selected references

Holloway J (1998) Geranium bronze Cacyreus marshalli Atropos 4: 3–6.

Quacchia A, Ferracini C, Bonelli S, Balletto E, Alma A (2008) Can the Geranium Bronze, *Cacyreus marshalli*, become a threat for European biodiversity? Biodiversity and Conservation 17: 1429–1437.

Sarto i Monteys V (1992) Spread of the Southern African Lycaenid butterfly, *Cacyreus marshalli* Butler, 1898, (LEP: Lycaenidae) in the Balearic Archipelago (Spain) and considerations on its likely introduction to continental Europe. Journal of Research on the Lepidoptera 31: 24–34.

14.74 – *Spodoptera littoralis* (Boisduval, 1833) - African cotton leaf worm (Lepidoptera, Noctuidae)

Carlos Lopez-Vaamonde

Description and biological cycle: Polyphagous moth, up to 2 cm long with wingspan of 4 cm (*Photo left*); eggs laid in batches covered with orange-brown hairs. The neonate larva is pale green with a brownish head; when fully developed, larvae 35–45 mm long, body colour varying from grey to reddish or yellowish, with a median dorsal line bordered on either side by two yellowish-red or greyish stripes, and small yellow dots on each segment (*Photo right- mature larva on a tomato leaf*). 1000–2000 eggs laid per female 2–5 d after emergence; egg masses of 100–300 on the lower leaf surface of host plants. Life cycle lasts 19–144 days. Larvae are extremely sensitive to climatic conditions, especially to combinations of high temperature and low humidity; temperatures above 40 °C or below 13 °C increase mortality.

Native habitat (EUNIS code): F5 - semi-arid and subtropical habitats.

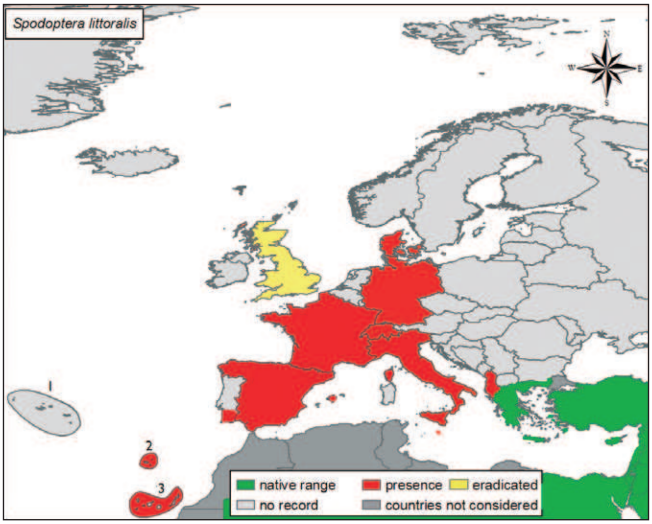
Habitat occupied in invaded range (EUNIS code): F5 - Maquis, matorral and thermo-Mediterranean brushes; F6 - Garrigue; F8 - Thermo-Atlantic xerophytic habitats; H5 - Miscellaneous inland habitats with very sparse or no vegetation; I1- Arable land and market gardens; I2 - Cultivated areas of gardens and parks; J100- Glasshouses.

Native range: Origin unclear, probably Egypt. Widespread in tropical and subtropical Africa and Southeastern Europe and Asia Minor.

Introduced range: One of the most commonly intercepted species in Europe, for example on imported ornamentals. Present outdoors in Sicily, southern Italy, Corsica, Spain, southern Portugal, and in Madeira and the Canary Islands but only in glasshouses in northern Italy, Western and Central Europe (*Map*). Not established in Great Britain.

Pathways: Trade appears to be the most likely pathway for introduction, through eggs and larvae present on imported commodities such as glasshouse crops, both ornamentals and vegetables from infested areas. Flight range of moths can be 1.5 km during a period of 4 h

Credit: Paolo Mazzei (left), Jean Yves Rasplus/ INRA (right)



overnight. Adult moths can also be spread through wind, attached to or transported by another organism or through other natural means.

Impact and management: *Spodoptera littoralis* is one of the most destructive agricultural lepidopteran pests within its subtropical and tropical range, attacking plants from 44 families including grasses, legumes, crucifers and deciduous fruit trees. In North Africa damages vegetables, in Egypt cotton, and in Southern Europe, plant and flower production in glasshouses or vegetables and fodder crops. It is important to seek assurance from suppliers that plants are free from this pest as part of any commercial contract. Avoid importing plant material from infested areas. Carefully inspect new plants on arrival, including any packaging material, to check for eggs and caterpillars and for signs of damage. As the adults are nocturnal, light or pheromone traps should be used for monitoring purposes. Mechanical control: physical destruction of insects and any plant material infested by this pest is recommended. Egg masses can be hand collected. Chemical control: there are many cases of resistance to insecticides. Biological control: includes the use of microbial pesticides, insect growth regulators and slow-release pheromone formulations for mating disruption.

Selected references

Abdel-Megeed MI (1975) Field observations on the vertical distribution of the cotton leafworm, *Spodoptera littoralis* on cotton plants. Zeitschrift für Angewandte Entomologie 78: 597–62.

Brown ES, Dewhurst CF (1975) The genus *Spodoptera* (Lepidoptera, Noctuidae) in Africa and the Near East Bulletin of Entomological Research 65: 221–262.

EPPO/OEPP (2003) Fiche informative sur les organismes de quarantaine. *Spodoptera littoralis* and *Spodoptera litura.* http://www.eppo.org/QUARANTINE/insects/Spodoptera_littoralis/F-spodli.pdf.

14.75 – *Epichoristodes acerbella* (Walker, 1864) - African Carnation Tortrix (Lepidoptera, Tortricidae)

Stanislav Gomboc

Description and biological cycle: Small moth, 14–24 mm wingspan, female larger than male. Forewing ochreous yellow to brownish yellow, often with a darker band towards the distal edge; hindwings greyish-white (*Photo left*). Number of generations depends on temperature. In Africa, the moth has several generations yearly, without diapause. In southern Europe, there are 3–4 generations (April - October) outdoors and 4–5 generations in glasshouses. Generations are difficult to distinguish since all stages are present for most of the year. Female lays 200–240 eggs in groups of 80–120 eggs in a period of three days, on the upper side of the leaf. Eggs hatch after about ten days. Lower threshold of their development is about 6°C, but they are able to withstand lower temperatures in the hibernation period. Larva variable in colour, green, yellowish or grey, with darker dorsal and subdorsal lines (*Photo- right*). Pupation occurs after about 30 d and the pupal stage lasts eight d. The development from egg to adult is influenced by temperature: 11°C - 170 d, 17°C – 70 d, 20°C - 40 d. Host plants mainly include *Dianthus* and *Chrysanthemu*m but also *Pelargonium, Medicago*, *Lupinus*, *Lycopersicon*, *Rosa*, *Capparis*, *Pyrus*, *Malus*, *Prunus, Rhamnus,* and some weeds such as *Sonchus*, *Rumex*, *Oxalis, Carex*, *Erigeron*, *Ornitogalum* and others.

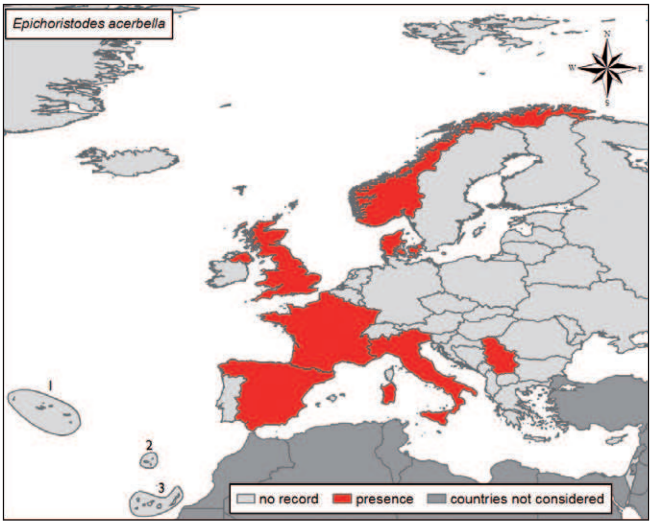
Native habitat (EUNIS code): Unknown.

Habitat occupied in invaded range (EUNIS code): Mainly J100- glasshouses ; but also I1- Arable land and market gardens; I2- Cultivated areas of gardens and parks ; FB- Shrub plantations; Shrub plantations for ornamental purposes ; F5- Maquis, arborescent matorral and thermo-Mediterranean brushes.

Native range: South Africa, Eastern Africa (Kenya) and Madagascar.

Introduced range: Firstly reported in Europe in mid-1960s from glasshouses in Scandinavian countries. At present, regional distribution in France, Italian mainland, Sardinia, Sicily,

Credit: Stanislas Gomboc



Spanish mainland, south England, Serbia and also in plantations in Germany and Danish mainland (*Map*). Intercepted many times on cut flower shipments in other European countries, but not yet established there.

Pathways: Passive international transport (airplanes, vehicles) of cut flowers and ornamental plants is the quickest means of spread. Adults fly only on short distances but the moth can disperse in any of its development stage, early stages being hidden on or inside plant tissue.

Impact and management: Important indoor and outdoor pest of cultivated, mainly ornamental plants. In European carnation cultivars, African Carnation tortrix may attack up to 90% of the crop; an important pest of *Chrysanthemum* and some field crops. Larvae are polyphagous and feed first on the leaf, under a shelter of silk, later in buds, flowers or stems. Young leaves are perforated and wilt and, more typically, stems are mined; flower buds are also perforated, become desiccated and petals are often woven together by silk. Difficult to control, due to hidden lifestyle. Spraying or fumigation with insecticides is still the best control method. Avoid importing plant material from infested areas or inspection of plants on arrival. The adults are nocturnal, and can be monitored by pheromone traps or by light traps; eggs, larvae and pupae by observation of presence on plants or plant damage. Biological control is still under investigation: possibly by using mating disruption with pheromones or by parasitoids like trichograms (*Trichogramma dendrolimi*, *T. voegelei*, *T. dendrolimi*).

Selected references

Costa Seglar M, Vives Quadras JM (1976) *Epichoristodes acerbella* Walk, nuevo tortrícido, plaga de los claveles, en la Península Ibérica. SHILAP Revista de Lepidopterologia 4: 233–234.

Zangheri S, Cavalloro R (1971) Sulla presenza in Italia di *Epichoristodes acerbella* (Walker) (Lepidoptera Tortricidae). Bolletino della Società Entomologica Italiana 103: 186–190.

14.76 – *Grapholita molesta* (Busck, 1916) - Oriental fruit moth (Lepidoptera, Tortricidae)

Zdeněk Laštůvka

Description and biological cycle: Wingspan 11–13 mm, body length 6–7 mm; small tortricid moth, forewing dark, greyish black, more or less distinct black transverse lines, oblique strigulae on the costa, black spots along distal margin and distinct light spot in the middle of the distal half of the wing (*Photo left*); very similar to the native European plum fruit moth (*Grapholita funebrana*); reliable determination possible only after genitalic dissection; oligophagous on *Prunus* s.l. spp. (peach, nectarine, apricot, almond, plum, cherry), on apple (*Malus*), pear (*Pyrus*), occasionally on quince (*Cydonia*), medlar (*Mespilus*), hawthorn (*Crataegus*), loquat (*Eriobotrya japonica*), *Cotoneaster*, *Eugenia* and *Photinia*; the species develops 2–4 generations per year following climatic conditions and adults are on wing between May and October; female lies about 200 eggs during its life lasting 10–14 days; eggs are whitish, flattened, oval in shape, 0.7–0.8 mm long; they are laid usually on the leaf underside, less often on new shoots or on fruits; larva of the first generation bores tunnels in terminal parts of young shoots; of following generations it lives usually in fruits (*Photo right- frass exiting from infested fruit*); mature larvae of the last generation overwinter in cocoons in crevices under bark or in the soil litter and they pupate in early spring.

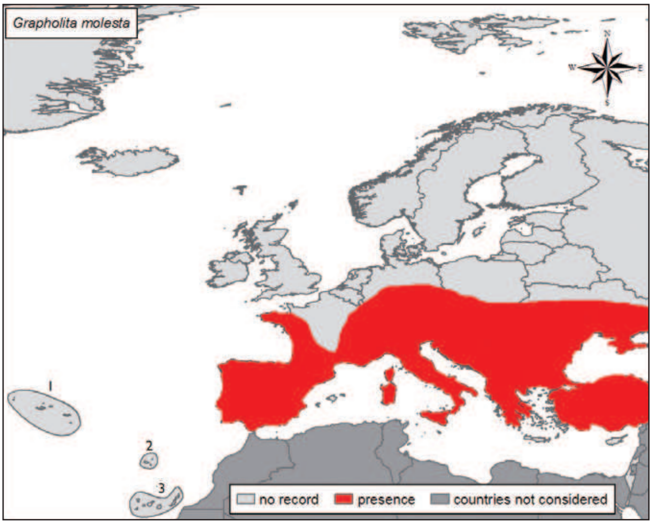
Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): I1 - Arable land and market gardens; I2 - Cultivated areas of gardens and parks (fruit orchards, lines of fruit trees, fruit gardens, ornamental cultures).

Native range: East Asia (China, Korean Peninsula, Japan).

Introduced range: Introduced over the world mostly during the first three decades of the 20th century. Described as new species by Busck from the introduced range (USA, Virginia) in 1916. In Europe recorded for the first time in 1920 in Italy and France. Today present in Western, Central, Southern and Southeastern Europe (*Map*); not known from Poland, but very probably present, occasionally imported with fruit into more northern countries such as

Credit: Rémi Coutin/ OPIE



Great Britain, Belgium, Denmark, Sweden, Lithuania, Latvia, Byelorussia, but probably not naturalized there. Also recoreded from other temperate and partly subtropical regions of the world: Southwestern Asia (Armenia, Azerbaijan, Georgia, southern Kazakhstan - possibly native, Uzbekistan - possibly native), Africa (Morocco, Southern Africa), North America (USA, southern Canada – Ontario, North Mexico), southern parts of South America (Argentina, southern Brazil, Chile, Uruguay), eastern half of Australia, and New Zealand.

Pathways: Mostly passive transport of cocoons on dormant fruit-tree nursery stock and in containers with fruits, or directly with infested fruits. Dispersal at a local scale is realized by active flight of adults.

Impact and management: The oriental fruit moth is one of the most important pests of stone and other fruit trees (especially on peaches and nectarines) causing considerable economic damage. Ecological impact is not known, but an influence on native parasitoid abundance and their trophic chains is possible. Monitoring is possible using pheromone traps. A number of insecticides were used for chemical control during the last decades (various organophosphates, pyrethroids, carbamates, neonicotinoids, insect growth regulators). Biological control possibilities include various kinds of bioagents tested or applied locally as granuloviruses, *Bacillus thuringiensis*, entomoparasitic nematodes (*Steinernema* and *Heterorhabditis* spp.); also hymenopteran (several Ichneumonidae, Pteromalidae, *Trichogramma* spp., etc.) and dipteran (Tachinidae) parasitoids. Mating disruption by synthetic sexual pheromones was largely used during recent years.

Selected references

Kyparissoudas DS (1989) Control of *Cydia molesta* (Busck) by mating disruption using Isomate-M pheromone dispensers in northern Greece. Entomologia Hellenica 7: 3–6.

Paoli G (1922) Un lepidottero nuovo per la fauna italiana (*Laspeyresia molesta* Busck). Bollettino della Società Entomologica Italiana 54: 122–126.

14.77 – *Argyresthia thuiella* (Packard, 1871) - Arborvitae leaf miner (Lepidoptera, Yponomeutidae)

Ferenc Lakatos

Description and biological cycle: Tiny moth, adults with wingspan of 4–6mm. Forewings silvery, tip brownish. Larvae rosy with black head. Females lay eggs after mating on the foliage in June (*Photo left - detail of an egg*). After hatching, larvae enter the leaves, where they feed, overwinter and also pupate. Larva starts feeding at the tip of branch towards trunk. Branch tip becomes yellowish (*Photo right*), later brown. This species has one generation both in Europe and in the native area (Eastern North-America). Adults fly around the host trees, different *Thuja* species, during the daytime.

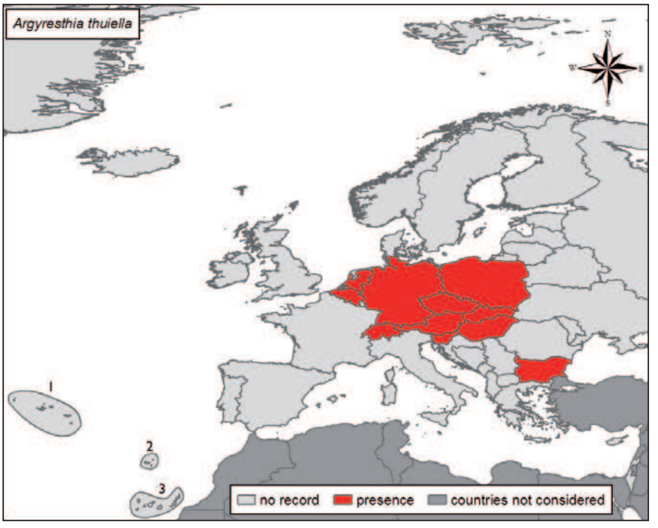
Native habitat (EUNIS code): G- Woodland and forest habitats and other wooded land.

Habitat occupied in invaded range (EUNIS code): G5- Lines of trees; I2- Cultivated areas of gardens and parks.

Native range: North America.

Introduced range: Supposedly introduced three times independently (1971: the Netherlands; 1975: Germany; 1976: Austria). *Argyresthia thuiella* expanded its distribution in the

Credit: Hana Šefrová



last decades to most of continental Europe, except Scandinavia and Iberian Peninsula (*Map*). However damage caused by this species has decreased with this expansion.

Pathways: Probably trade of ornamental Cupressaceae.

Impact and management: Damage was important only during his expansion phase after establishment. At present, frequent in urban areas such as parks, gardens and urban forests. Several parasitoids were reared from different developmental stages already at the start of this moth's presence in Europe (e.g. Pteromalidae, Eulopidae and Braconidae). After establishment, chemical suppressants were widely used, but as damage decreased so did the need for control. Attractants are known and available for the members of the genus *Argyresthia*, but not so far used for monitoring or mass trapping.

Selected references

Frankenhuyzen Av (1974) *Argyresthia thuiella* (Pack.) (Lep., Argyresthiidae). Entomologische Berichten 34: 106–111.

Škerlavaj V, Munda A (1999) *Argyresthia thuiella* Packard - a new pest of Thuja in Slovenia. Zbornik predavanj in referatov 4. slovenskega posvetovanja o varstvu rastlin v Portorožu od 3. do 4. Marca 1999, Ljubljana: Društvo za varstvo rastlin Slovenije, p. 451.

14.78 – *Frankliniella occidentalis* (Pergande, 1895) - Western flower thrips (Thripidae, Thysanoptera)

Alain Roques

Description and biological cycle: Tiny, slender thrips with narrow fringed wings (*Photo*). Males, 1.2–1.3 mm long, are pale yellow, females, 1.6–1.7 mm long, are yellow to brown; larvae are yellowish-white. Adults and larvae suck plant fluids from flowers and leaves of at least 244 plant species from 62 families. Western flower thrips reproduces in glasshouses with 12–15 generations/year. Overall life cycle lasts from 44 d at 15 °C to 15 d at 30 °C. A female can lay 20–40 eggs. Unmated females produce males. Different developmental stages are typically found in different parts of plants: eggs in leaves, flower tissue and fruits; nymphs on leaves, in buds and flowers; pupae in soil or in hiding places on host plants such as the bases of leaves; adults on leaves, in buds and flowers.

Native habitat (EUNIS code): I - Regularly or recently cultivated agricultural, horticultural and domestic habitats.

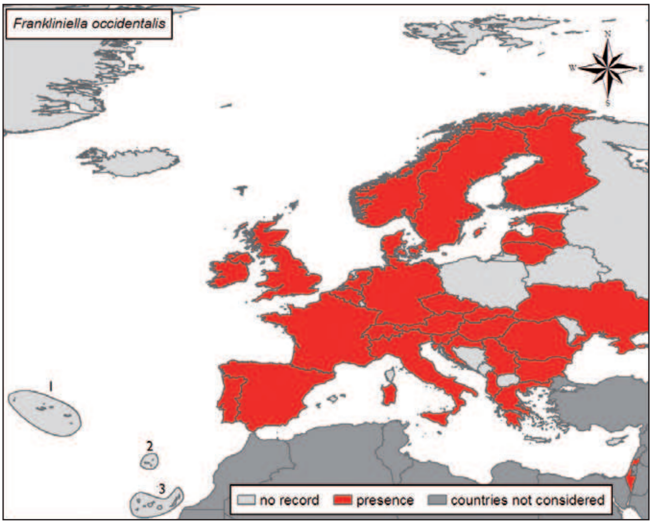
Habitat occupied in invaded range (EUNIS code): I1- Arable land and market gardens; J100 - glasshouses.

Native range: North America.

Introduced range: Reported from all continents; first record in Europe in 1983 in the Netherlands; continuous and rapid spread since the 1980s; present in glasshouses in North and central Europe, but already outdoors in Southern Europe (*Map*).

Pathways: Intercontinental dispersal of eggs, larvae and adults is taking place with the trade of ornamental plants (e.g., cut flowers, potted plants). Adults can be easily carried by winds, but also by clothes, equipment and containers not properly cleaned.

Credit: Philppe Reynaud



Impact and management: An outdoor pest as well as a glasshouse pest. Flowers and foliage of a great number of economically important crops are affected, in glasshouses as well as outdoors. On ornamental flower crops, feeding induces discolouration, indentation, distortion and silvering of the upper leaf surface as well as scarring and discolouration of petals and deformation of flower heads, largely reducing their economic value. In orchids, eggs laid in petal tissues cause a 'pimpling' effect on flowers. This thrips also kills or weakens terminal buds and blossoms in fruit trees (e.g., apricot, peach) and roses, and on most fruiting vegetables, especially cucumbers. In addition, nymphs are vectors of tobacco streak ilarvirus (TSV) and tomato spotted wilt virus (TSWV), which is inducing severe diseases in ornamental and vegetable crops in Europe. Blue sticky traps can be used to detect initial infestation and to monitor adult population levels. Chemical control is difficult because this thrips is resistant to most pesticides and feeds deep within the flower or on developing leaves. Biological predatory mites (e.g., *Neoseiulus cucumeris, Amblyseius* spp. and *Hypoaspis* spp.) and minute pirate bugs (e.g., *Orius laevigatus, O. insidiosus*) provide effective biological control, in glasshouses.

Selected references

Del Bene G, Gargani E (1989) [A contribution to the knowledge of *Frankliniella occidentalis*] (in Italian). Redia 72: 403–420.

EPPO/CABI (1997). *Frankliniella occidentalis.* Quarantine Pests for Europe. Wallingford, United Kingdom: CAB International, 267–272.

Mantel WP (1989) Bibliography of the western flower thrips, *Frankliniella occidentalis*. Bulletin SROP 12: 29–66.

14.79 – *Pseudodendrothrips mori* (Niwa, 1908) - Mulberry thrips (Thripidae, Thysanoptera)

Philippe Reynaud

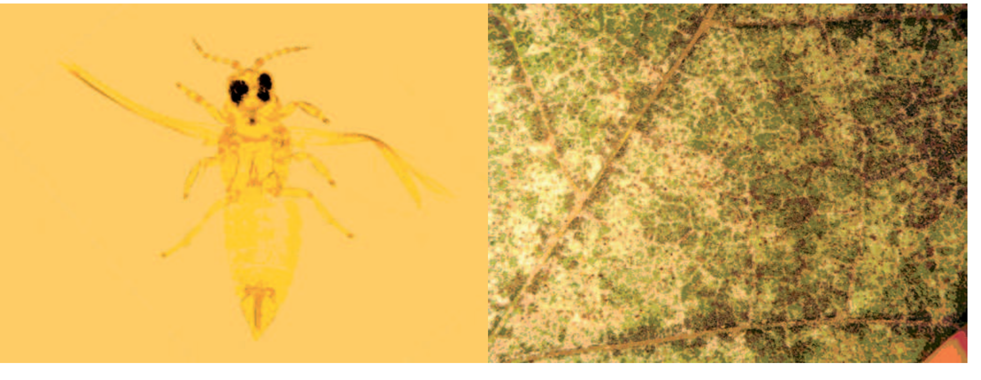
Description and biological cycle: Oligophagous thrips with small to minute and very pale bodies. Males 0.7–0.9 mm long; females 0.9–1.1 mm long. Mulberry thrips is a member of the Dendrothripinae subfamily distinguished from other Thripidae by the presence of a remarkably elongate *metasternal endofurca** providing active jumping capacities (*Photo left*). *Pseudodendrothrips mori* commonly breeds on *Morus alba* and *M. bombycis* or on *Ficus* throughout the world and is a widespread although minor pest of *Morus* (*Photo right - damage on leaf*). Mulberry thrips reproduces outdoors with 6–10 generations per year in its native area. In mid-March, overwintering adults emerge to damage the leaves. The complete life cycle lasts 26–34 days in spring and autumn, and 16–23 days in summer, depending on conditions. Increased temperature (26–32°C) directly influence the breeding activity of the thrips and thereby increases the population levels. July and August are peak months of occurrence; the final stage of appearance is in late autumn. Adults overwinter after October, thus completing the annual life cycle. Seasonal population fluctuations and the degree of damage caused to the host plant are influenced by various environmental factors, including climate, host plant variety, topography, soil type and management regimes.

Native habitat (EUNIS code): Unknown.

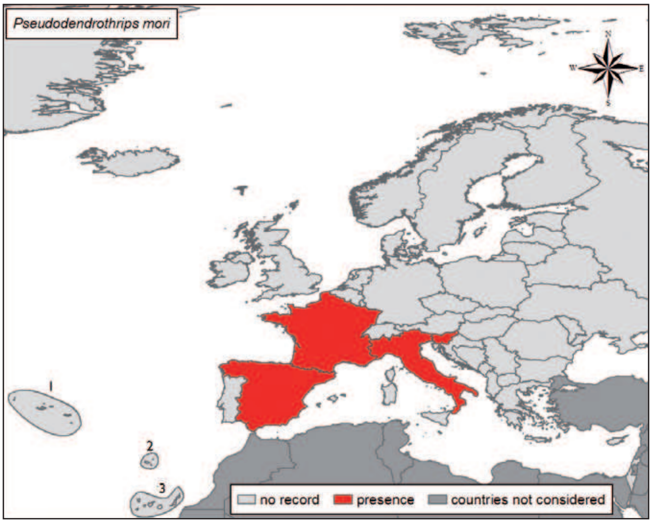
Habitat occupied in invaded range (EUNIS code): I2- Cultivated areas of gardens and parks.

Native range: Probably originated from China or Japan.

Introduced range: Recorded from several parts of the world, including USA, India, Iran and Australia. First recorded in 1974 in Italy; at present known only in few more countries (Spain and France). The rate of spread seems to be low.



Credit: Georgi Trenchev and Katia Trencheva



Pathways: Probably trade of ornamental plants.

Impact and management: Mulberry leaves are the exclusive food of the silkworm, *Bombyx mori*. Mulberry thrips have caused serious damage to sericulture in the southern states of India and China while damage to this industry is also reported in Sri Lanka and Vietnam. Feeding silkworms with mulberry leaves that have been damaged by mulberry thrips causes slower development, increases larval mortality and reduces cocoon yield. In other countries such as Japan, Iran and some countries in Europe and America, production of silk is very limited. Here mulberry is mainly an ornamental tree which is grown by roads because of its low need for water and nutrients, and *P. mori* can damage plants growing in these situations. Chemical control is the main method used to control *P. mori* in silk production areas. However, it is assumed that in countries where *Morus* are used as ornamental plants, damage by the pest could be mitigated using non-chemical methods which are economically or ecologically tolerable.

Selected references

Cappellozza L, Miotto F (1975) *Pseudodendrothrips mori* (Niwa) (Thysanoptera Terebrantia) specie nuova per la fauna Italiana. Redia 56: 387–389.

Trenchev G, Trencheva K (2007)*Pseudodendrothrips mori* Niwa (Thysanoptera, Thripidae), a species new to the Bulgarian fauna. Zachita na Rastenija 18: 68–71.

Vierbergen G, Cean M, Szeller IH, Jenser G, Masten T, Simala M (2006) Spread of two thrips pests in Europe: *Echinothrips americanus* and *Microcephalothrips abdominalis* (Thysanoptera: Thripidae). Acta Phytopathologica et Entomologica Hungarica 41: 287–296.

14.80 – *Thrips palmi* (Karny, 1925) - Melon thrips (Thripidae, Thysanoptera)

Philippe Reynaud

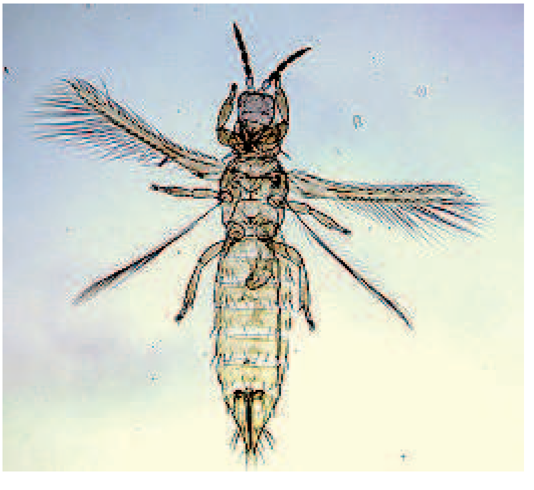
Description and biological cycle: Completely yellow thrips (*Photo*). Males 0.9–1.0 mm long, females 1.1–1.3 mm long. Identification is hampered by small size and a great similarity with other yellow species of *Thrips*. Melon thrips is a polyphagous feeder and an outdoor pest of aubergine (*Solanum melongena*), sweet pepper (*Capsicum annuum*), cotton (*Gossypium* spp.) cowpea (*Vigna unguiculata*), cucumber (*Cucumis sativus*), *Cucurbita* spp., melon (*Cucumis melo*), pea (*Pisum sativum*), *Phaseolus vulgaris*, potato (*Solanum tuberosum*), sesame (*Sesamum indicum*), soyabean (*Glycine max*), sunflower (*Helianthus annus*), tobacco (*Nicotiana tabacum*) and watermelon (*Citrullus lanatus*). In glasshouses, economically important hosts are aubergine, *Capsicum annuum*, *Chrysanthemum*, cucumber, *Cyclamen*, *Ficus* and Orchidaceae. To develop from egg to adult, *Thrips palmi* requires 194 day-degrees above a thermal threshold of 10.1°C, and takes between 10 days (at 30°C) to 40 days (at 15°C) to complete its life-cycle which is lengthened to 80 days when the insects are at 13°C. Melon thrips are able to multiply during any season that crops are cultivated, but are favoured by warm weather.

Native habitat (EUNIS code): I1- Arable land and market gardens.

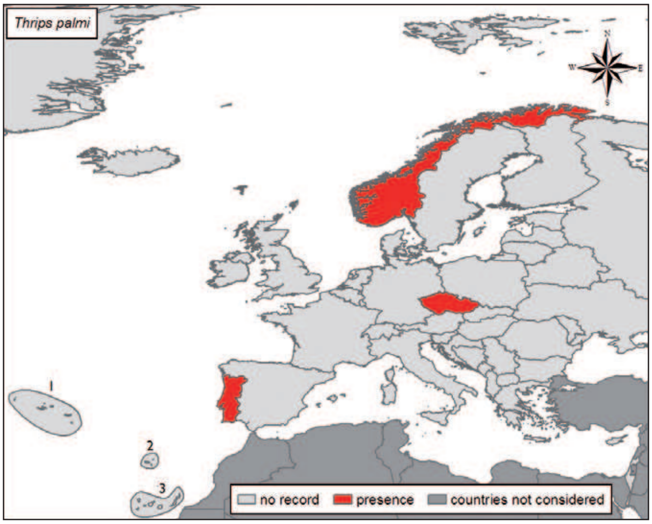
Habitat occupied in invaded range (EUNIS code): I- Regularly or recently cultivated agricultural, horticultural and domestic habitats; J- Constructed, industrial and other artificial habitats.

Native range: First described in 1925 in Sumatra but remained little known, often overlooked and the subject of taxonomic confusion until 1980.

Introduced range: From the late 1970s, Melon thrips has spread across the Far East and in subsequent decades within South East Asia, and to Australia, the Pacific, Florida, the Car-



Credit: LNPV



ibbean, South America and West Africa. In Europe, numerous interceptions have been reported on cut flowers and fruit vegetables from Thailand, Mauritius, India, etc. Several limited outbreaks were found in glasshouses in Netherlands and in Great Britain since 1988, but all these outbreaks were eradicated. May-be still present in glasshouses of Norway and the Czech Republic. *T. palmi* is considered to be absent outdoors in Europe although it was detected in flowers of kiwi fruit (*Actinidia deliciosa*) plantations in Portugal in 2004; in later surveys the pest was no longer found.

Pathways: Trade of plant material (ornamentals, vegetables, fruits).

Impact and management: Melon thrips cause severe injury to infested plants. Leaves become yellow, white or brown, and then crinkle and die. Heavily infested fields sometimes acquire a bronze color. Terminal growth damage occurs via discolouration, stunting, or deformation. Fruits may also be damaged with scars, deformities and abortion. *T. palmi* has been shown to transmit plant viruses including Groundnut bud necrosis virus (GBNV), Melon yellow spot virus (MYSV), Watermelon silver mottle virus (WSMoV), Tomato spotted wilt virus (TSWV) and Capsicum chlorosis virus (CaCV). However, this list is questionable due to lack of consistent studies. Experience of controlling or eradicating *T. palmi* has been gained in a large number of countries as this pest has spread around the world. However, melon thrips requires frequent spraying of insecticides, so resistance to many chemicals has developed. It is now considered that control with insecticides alone is not adequate. Integrated pest management is necessary, including cultural practices and biological control.

Selected references

Anonymous (2004). First report of *Thrips palmi* in Portugal. EPPO Reporting Service 144: 2.

Cannon RJC, Matthews L, Collins DW, Agallou E, Bartlett PW, Walters KFA, MacLeod A, Slawson DD, Gaunt A (2007) Eradication of an invasive alien pest, *Thrips palmi*. Crop Protection 26: 1303–1314.

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Abbreviations and glossary of technical terms used in the book

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Appendix I

Country codes abbreviations used in the book according to the International Organization for Standardization list ISO 3166. http://www.iso.org/iso/english_country_names_and_code_elements.

Abbreviation	Country/ Island
AD	Andorra
AL	Albania
AT	Autriche
BA	Bosnia and Herzegovina
BE	Belgium
BG	Bulgaria
BY	Belarus
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
ES-BAL	Spain - Baleares islands
ES-CAN	Spain - Canary islands
FI	Finland

Abbreviation	Country/ Island
FI-ALN	Finland - Aland
FÖ	Faroe islands
FR	France
FR-COR	France - Corsica island
GB	United Kingdom
GI	Gibraltar
GL	Greenland
GR	Greece
GR-CRE	Greece - Crete
GR-ION	Greece - Ionian islands
GR-NEG	Greece - North Aegean islands
GR-SEG	Greece - South Aegean islands
HR	Croatia
HU	Hungary
IE	Ireland

Abbreviation	Country/ Island	Abbreviation	Country/ Island
IL	Israel	**NO**	Norway
IS	Iceland	**NO-SVL**	Norway - Svalbard
IT	Italy	**PL**	Poland
IT-SAR	Italy - Sardinia island	**PT**	Portugal
IT-SIC	Italy - Sicily island	**PT-AZO**	Portugal - Azores islands
LI	Liechtenstein	**PT-MAD**	Portugal - Madeira island
LT	Lithuania	**RO**	Romania
LU	Luxembourg	**RS**	Serbia
LV	Latvia	**RU**	Russia (European Part)
MD	Moldova	**SE**	Sweden
ME	Montenegro	**SI**	Slovenia
MK	Macedonia	**SK**	Slovakia
MT	Malta	**UA**	Ukraine
NL	Netherlands	**YU**	Former Yugoslavia

Appendix II

Habitat abbreviations used in the book according to the European Nature Information System (EUNIS) database. http://eunis.eea.europa.eu

Code	Habitat
A	**Marine habitats**
B	**Coastal habitats**
B1	Coastal dune and sand habitats
B2	Coastal shingle habitats
B3	Rock cliffs, ledges and shores, including the supralittoral
C	**Inland surface water habitats**
C1	Surface standing waters
C2	Surface running waters
C3	Littoral zone of inland surface waterbodies
D	**Mire, bog and fen habitats**
D1	Raised and blanket bogs
D2	Valley mires, poor fens and transition mires
D3	Aapa, palsa and polygon mires
D4	Base-rich fens
D5	Sedge and reedbeds, normally without free-standing water
D6	Inland saline and brackish marshes and reedbeds
E	**Grassland and tall forb habitats**
E1	Dry grasslands
E2	Mesic grasslands
E3	Seasonally wet and wet grasslands
E4	Alpine and subalpine grasslands
E5	Woodland fringes and clearings and tall forb habitats

Code	Habitat
E6	Inland saline grass and herb-dominated habitats
E7	Sparsely wooded grasslands
F	**Heathland, scrub and tundra habitats**
F1	Tundra
F2	Arctic, alpine and subalpine scrub habitats
F3	Temperate and mediterraneo-montane scrub habitats
F4	Temperate shrub heathland
F5	Maquis, matorral and thermo-Mediterranean brushes
F6	Garrigue
F7	Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff vegetation)
F8	Thermo-Atlantic xerophytic habitats
F9	Riverine and fen scrubs
FA	Hedgerows
FB	Shrub plantations
G	**Woodland and forest habitats and other wooded land**
G1	Broadleaved deciduous woodland
G2	Broadleaved evergreen woodland
G3	Coniferous woodland
G4	Mixed deciduous and coniferous woodland
G5	Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice
H	**Inland unvegetated or sparsely vegetated habitats**
H1	Terrestrial underground caves, cave systems, passages and waterbodies
H2	Screes
H3	Inland cliffs, rock pavements and outcrops
H4	Snow or ice-dominated habitats
H5	Miscellaneous inland habitats with very sparse or no vegetation
H6	Recent volcanic features
I	**Regularly or recently cultivated agricultural, horticultural and domestic habitats**
I1	Arable land and market gardens
I2	Cultivated areas of gardens and parks
J	**Constructed, industrial and other artificial habitats**
J1	Buildings of cities, towns and villages
J2	Low density buildings
J3	Extractive industrial sites
J4	Transport networks and other constructed hard-surfaced areas
J5	Highly artificial man-made waters and associated structures
J6	Waste deposits
J100	Greenhouses
X	**Complex habitats**
X6	Crops shaded by trees
X7	Intensively-farmed crops interspersed with strips of spontaneous vegetation

Code	Habitat
X10	Mixed landscapes with a woodland element (bocages)
X11	Large parks
X13	Land sparsely wooded with broadleaved deciduous trees
X14	Land sparsely wooded with broadleaved evergreen trees
X15	Land sparsely wooded with coniferous trees
X16	Land sparsely wooded with mixed broadleaved and coniferous trees
X20	Treeline ecotones
X22	Small city centre non-domestic gardens
X23	Large non-domestic gardens
X24	Domestic gardens of city and town centres
X25	Domestic gardens of villages and urban peripheries

Glossary of the technical terms used in the book (marked by *)

Alatae: winged forms in aphids, adelgids, and other hemipterans.

Ampelophagous: related to the grapevine.

Anholocyclic: in cyclically parthenogenetic organisms, life cycles that do not include a sexual generation (e.g., in adelgids).

Archegonia: female multicellular egg-producing organ occurring in mosses, ferns, and most gymnosperms.

Archeozooan: an alien animal introduced to Europe since the beginning of the Neolithic agriculture but before the discovery of America by Columbus in 1492 (Daisie 2009).

Arrhenotoky: a common form of sex-determination in Hymenoptera and some other invertebrates, in which progeny are produced by mated or unmated females, but fertilized eggs produce diploid female offspring, whereas unfertilized eggs produce haploid male offspring by parthenogenesis (only the females are biparental).

Carina (sg.), **Carinae (pl.):** a ridgelike structure (e.g. antennal longitudinal ridge).

Cercus (sg.), **Cerci (pl.):** paired sensory structures at the posterior end of some arthropods.

Clava: apically differentiated region (sometimes club-like) of the antennal flagellum.

Dealate: having lost its wings; used for ants and other insects that shed their wings after the mating flight.

Declivity: posterior portion of the elytra that descends to its apex.

Domestic: living in human habitats.

Endofurca: the internal skeleton of the meso-and metathorax, that provides important muscle insertion points. In some thrips, the metasternal endofurca provides the insertion for powerful muscles that are associated with a remarkable jumping ability of adults.

Endophytic (adj): living inside a plant.

Endopterygote: insect that undergoes complete metamorphosis, with the larval and adult stages differing considerably in their structure and behaviour.

Epigyne: the external female sex organ in arachnids.

Exarate: for a pupa, having the appendages free and not attached to the body (as opposed to Obtect).

Exopterygote: insect that undergoes incomplete metamorphosis. The young (called nymphs) resemble the adults but lack wings; these develop gradually and externally in a series of stages or instars until the final moult produces the adult insect. There is no pupal stage.

Flagellum: the part of the antenna beyond the pedicel, which is differentiated into three regions, the anellus, funicle and clava.

Frass: waste material produced by feeding insects, including excrement and partially chewed vegetation.

Funicle: region of the antennal flagellum between the anellus and clava.

Gallicolae: leaf gall making forms; e.g., in phylloxerans.

Gnathosoma: anterior body region in mites.

Halobiont: an organism that lives in a salty environment.

Hemimetabolous: the type of insect development in which there is incomplete or partial metamorphosis, typically with successive immature stages increasingly resembling the adult; see Exopterygote.

Holocyclic: in cyclically parthenogenetic organisms, life cycles that include a sexual generation (e.g., in adelgids).

Holoptic: as in flies, with compound eyes meeting along the dorsal midline of the head.

Hyperparasitoid: a parasitoid living on or in another parasitoid.

Idiobiont parasitoid: a parasitoid which prevents further development of the host after initial parasitization.

Idiosoma: abdomen of mites and ticks.

Kleptoparasitoid: a parasitoid which preferentially attacks a host that is already parasitized by another species.

Koinobiont parasitoid: a parasitoid which allows the host to continue its development and often does not kill or consume the host until the host is about to either pupate or become an adult.

Ligula: the apical lobe of the labium.

Megagametophyte: female haploid, gamete-producing tissue in conifers.

Mesothorax: the second, and usually the largest, of the three primary subdivisions of the thorax in insects.

Mesonotum: the dorsal part of the mesothorax.

Metathorax: the third of the three primary subdivisions of the thorax in insects.

Metanotum: the dorsal part of the metathorax.

Moniliform: bead-like (as in antennae).

Mycangium (sg.), **mycangia (pl.):** usually complex structures on the insect body that are adapted for the transport of symbiotic fungi, usually spores.

Neozooan: an alien animal introduced to Europe after the discovery of America by Columbus in 1492 (Daisie 2009) .

Notaulix (sg.), **Notaulices (pl.):** one of a pair of grooves on the mesoscutum, from the front margin to one side of the midline and extending backward; divides the mesoscutum into three parts.

Obtect: for a pupa, having the legs and other appendages fused to the body.

Oniscomorph: the state as in 'pill' millipedes of being able to roll up in a ball.

Opisthosoma: posterior part of the body in spiders and mites.

Paranota: lateral wings.

Parthenogenesis, parthenogenetic (adj.): the production of offspring from unfertilized eggs. Special cases of this state are arrhenotoky, pseudo-arrhenotoky, and thelytoky.

Phytoplasma: prokaryotes that are characterized by the lack of a cell wall, associated with plant diseases.

Phytotelmatum (sg.), **Phytotelmata (pl.):** a small, water-filled cavity in a tree or any similar environment.

Podosoma: anterior section of idiosoma in ticks; serving as connecting area for the four pairs of legs.

Porrect: extended, especially forward; e.g., porrect mandibles.

Proctiger: the reduced terminal segment of the abdomen which contains the anus.

Prognathous: with the head more or less in the same horizontal plane as the body, and the mouthparts directed anteriorly.

Pronotum: the dorsal part of the prothorax.

Propodeum: the first abdominal segment.

Prosoma: anterior part of the body in spiders and mites; also called cephalothorax.

Prothorax: The first of the three primary subdivisions of the thorax in insects.

Pseudo-arrhenotoky: A form of sex-determination (especially in some scale insects and mites) in which males and females arise from fertilized eggs and are diploid. However, males become haploid by inactivation of the paternal genomic complement.

Puparium (sg.), **puparia (pl.):** the enclosing case of a pupa.

Reticulate: net-like, anastomosing.

Rostrum: beak-shaped projection on the head; e.g., in weevils.

Scutellum: the middle region of the mesonotum or metanotum, behind the scutum.

Scutum: the anterior part of the mesonotum or metanotum.

Secondary pest: a pest that attacks only weakened plants.

Sensorium: sensory structure present on antenna.

Siphunculi, **siphuncular (adj.):** pair of protruding horn-shaped dorsal tubes in aphids which secrete a waxy fluid.

Spatula sternalis: median cuticular sclerite, often bilobed, on the ventral side of the prothoracic segment of the last instars of some midge larvae; plays a role in larval locomotion.

Stigma: conspicuous, usually melanised area at the apex of a vein of the forewing, generally at the leading wing edge.

Sulcate: having narrow, deep furrows or grooves.

Synanthropic: ecologically associated with humans.

Tegula: Small, typically oval sclerite that covers the region of the mesothorax where the forewing and thorax articulate.

Thelitoky: A form of sex-determination (especially in Hymenoptera: Symphyta and Cynipidae) in which only diploid female progeny are produced by parthenogenesis.

Termen: distalmost edge of wing.

Transhumance: in the case of hives, moving to new environments, according to the change in season.

Xylophagous (adj.): feeding on wood.

Index of the latin names of the arthropod species mentioned in the book