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## NOTES ON THE STATUS OF TERRESTRIAL ARTHROPODS IN GALÁPAGOS

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(Translation assisted by Heidi Snell and K. Thalia East)

Despite far outnumbering the terrestrial vertebrates in species diversity and population numbers, comparatively little is known about the terrestrial invertebrates of the Galápagos Archipelago. Most publications about Galápagos fauna deal with the systematics, phylogeny, physiology, ecology, ethology and preservation of native vertebrates for which the islands are famous. Much work has also been conducted on introduced birds and mammals. In contrast, terrestrial arthropods have been given little attention.

In 1982, Friedman Köster, then director of the Charles Darwin Research Station (CDRS), asked in an annual report, 'How many species of introduced insects and invading invertebrates are there in the islands?'. At that time even the number of native invertebrates in Galápagos was unknown. This realization prompted some important changes. Three long-term studies on the systematics and evolutionary ecology of terrestrial arthropods in the archipelago were initiated. In 1982, K. Desender, J.P. Maelfait and I, from the Royal Belgian Institute of Natural Sciences in Brussels, began a study of Arachnids, Carabid beetles and Isopods. In 1985, Stewart Peck and several of his colleagues from Carleton University, Canada, started a study of several arthropod groups, especially beetles. Also in 1985, Heinrich and Irene Schatz of the University of Innsbruck, Austria, commenced a study of Oribatoid mites and Tenebrionid beetles. All three projects continue to this day and while the groups work independently, they have coordinated their projects to complement one another.

Before any serious ecological work on a arthropod group could be conducted in Galápagos it was necessary to have an understanding of the diversity and population numbers of all species inhabiting the islands. This required extensive taxonomic research to identify and describe the existing invertebrate fau-

na. Such information is also of interest to the Galápagos National Park Service (GNPS) and to CDRS for developing and implementing management policies and for studies of faunal changes occurring due to the ever increasing human population within the islands.

Linsley and Usinger (1966) compiled the first insect species list for Galápagos, enumerating some 618 species, treated in about 190 publications. The list was derived from results of collecting campaigns of 21 multidisciplinary expeditions ever since Charles Darwins visit in 1835. In a later supplement, Linsley (1977) added another 265 species, treated in 118 publications. These additions were principally the result of collecting efforts of the Galápagos International Scientific Program of the Californian Academy of Sciences in 1963-64 and the collecting campaign of Leleup (1965) in 1964-65.

With this initial list, the first task of the Belgian, Canadian and Austrian research groups was to compile summaries of known data on terrestrial invertebrates in Galápagos. A data base was constructed, containing the following types of information:

- 1) Literature citations for all invertebrate species of the archipelago.
- 2) Distribution information of each species within and between islands as well as on the continent.
- 3) Whether each species is introduced, native or "endemic".
- 4) Ecological data for each species, such as habitat preference, seasonality, elevational zonation, dispersal power, diet and host specificity.

All major islands and volcanoes have been at least roughly sampled by the scientists. Due to improved arthropod capturing techniques such as pitfall, malaise, flying interception and bait traps the teams were able to almost double the arthropod species list during the 1980s (see Table 1). Even now a collection

**Table 1.** Growing number of species for the most important terrestrial arthropod groups.

	<u>1966</u>	<u>1980</u>	<u>1991</u>
Insecta	618	883	1592
Scorpions	2	0	2
Pedipalpi	0	0	1
Solifugae	0	0	1
Pseudoscorpiones	0	0	16
Opiliones	0	0	1
Araneae	70	81	152
Acari	38	0	192
Amphipoda	0	0	4
Isopoda	0	0	17
Chilopoda	10	0	13
Diplopoda	2	0	9
Symphyla	0	0	1

made on any island or volcano can add a new species to the list. Table 2 provides a detailed example of how the total number of spider (Araneae) species recorded in Galápagos has increased after each collecting trip.

Due to the efforts of the teams, we have a fairly good idea of the composition of some of the arthropod groups in the archipelago and have been able to conduct ecological analyses of the data. For example, we have been able to compare spider communities among the different vegetation zones of Santa Cruz Island (Baert et al., 1991) and of the five volcanoes on Isabela Island (Baert et al., 1990). We have concluded that species composition of spiders is correlated primarily with the altitudinal gradient and thus the vegetation zones. On Isabela spider communities are also influenced by the age of the volcanos as well as by the presence or absence of human settlements and agriculture.

K. Desender has been investigating distribution patterns of Carabid beetles (Desender et al., 1992a). He has shown that the Carabid beetles have a wide variety of distribution and speciation patterns includ-

ing small and large scale allopatry, parapatry, allopatry with secondary contact of sister species, and allo-parapatry. The same is true for spiders (e.g. Maelfait & Baert, 1986) and may be intrinsic to small arthropods.

Another important group of invertebrates in Galápagos is the cave dwelling Cryptozoa. Other than some fossil remnants of a probably endemic rat, the only animals found in caves are invertebrate representatives of Crustacea, Arachnida, Chilopoda, Diplopoda and Insecta. Leleup (1965) pioneered a study of cave animals in Galápagos which is now being followed up by S. Peck and his team (see Hernandez Pacheco et al., 1992). Cryptozoic arthropods are of special interest in studying the principals and historical processes of animal geography. They are often considered archaic or relictual and as having an exceedingly slow dispersal potential. Some Cryptozoans have adapted to an extreme and can be morphologically characterized by reduced or absent eyes, a reduction of body pigmentation, often a thinning of body cuticle, flightlessness in normally winged groups and an increased physiological sensitivity to

**Table 2.** Growing number of spider species.

<u>Year</u>	<u>Number of Species Added</u>	<u>Total Number of Species</u>	<u>Collecting Expedition</u>
1877	6	6	
1889	5	11	
1902	17	38	Hopkins-Stanford 1898-1899
1924	5	43	Williams 1923
1930	6	49	Norwegian Zoological 1925
1970	21	70	Cal. Acad. Sci. and Leleup ('64-'65)
1982	11	81	Various publications
1982	29	110	Baert and Maelfait
1985	2	112	H. and I. Schatz (1991)
1985	3	115	Peck et al.
1986	7	122	Baert, Maelfait and Desender (1989)
1988	4	126	Baert, Desender and Maelfait (1991)
1989	8	134	Peck et al. (1991)
1991	11	145	Baert, Desender and Maelfait (1991)
1991	4	149	Peck and Heraty
1992	3	152	Abedrabbo

dehydration. Peck (1990) lists 56 species of eyeless and reduced-eyed arthropods, of which 40 are native or endemic and 16 have become well established since their probably inadvertent introduction by man.

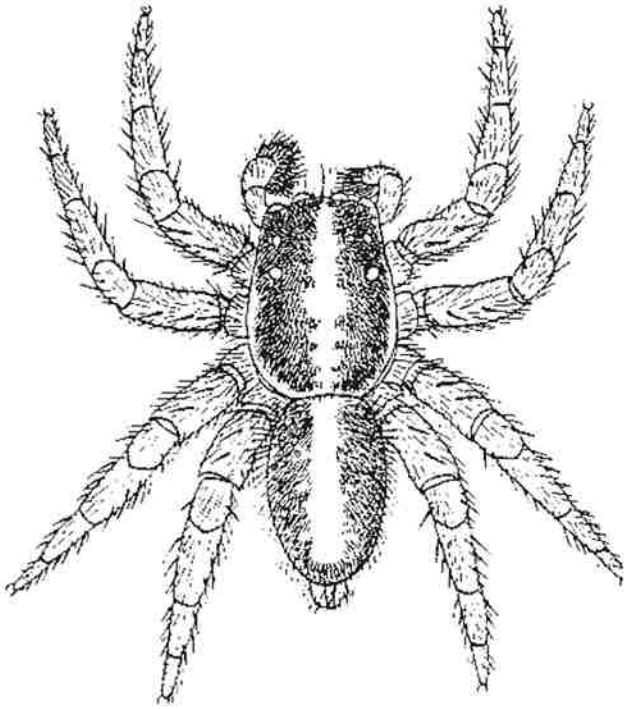
### INTRODUCED ARTHROPODS

While a large proportion of arthropod species in Galápagos certainly colonized the islands naturally, it is obvious that a number have been introduced since the islands were discovered and inhabited by humans. Kramer (1984) stated that the problem of introduced invertebrates, many of which may be man-dependent immigrants, had not yet been and needed to be tackled. Part of the problem was that it is often difficult to know whether a non-endemic species was introduced by man or immigrated naturally. No doubts exist in the case of man-dependent immigrants, examples of which are the spiders *Heteropoda venatoria*, which inhabits almost every house in Galápagos, the

long-legged *Scytodes longipes*, and all the beautiful jumping spiders around Puerto Ayora, Santa Cruz, such as *Hasarius adansonii*, *Menemerus bivittatus* and *Plexippus paykulli* (Fig. 1). *Theridion rufipes*, which lives both indoors and out and is often found under the plank beds of tourist boats, tends to be carried from island to island. *Latrodectus geometricus* which I have only found under wooden seats at the Canal de Itabaca (Santa Cruz Island) and in the town of Puerto Baquerizo Moreno (San Cristóbal Island) is another example of an introduced man-dependent spider.

The true number of introduced species is difficult to assess because few extensive studies of arthropod groups in Galápagos have been published. However, it is known that 13 out of 18 cockroach species (Peck and Roth, 1992), 7 out of 8 Diplopod species (Shear and Peck, 1987) and 10 out of 13 Chilopod species (Shear and Peck, 1992) have been introduced to the islands by man.

Introduced species can negatively affect existing



**Figure 1.** Sketch of an introduced jumping spider, *Plexippus paykulli* (Salticidae), by L. Baert.

ecosystems. Arthropods can be as devastating to plant and animal communities as can vertebrates such as goats, pigs and rats. However, their influence on the natural community also depends on the achieved equilibrium state of the natural community. For example, species which can fill an empty niche or which are able to adapt to harsh conditions of a specific microhabitat not occupied by a native species, can evolve to play a benign or even a beneficial role in the ecosystem. On the other hand, in Galápagos, difficulties of natural colonization in the islands have resulted in simpler arthropod assemblages than those found on the continent. This in turn may have made them more vulnerable to human-assisted introduction of aggressive species.

In 1972, at the Galápagos Science Conference held in Washington DC, the continuation of "alpha level" systematics for the diverse but still poorly known invertebrate fauna in Galápagos was recommended. However, it was only in 1981 that the position of a staff entomologist at the Charles Darwin Research Station (CDRS) was established and that Dr. Yale Lubin was hired to study, among other things, the

rapid spread of the introduced fire ant *Wasmannia auropunctata* (Lubin, 1984; 1985).

*W. auropunctata* was probably introduced to inhabited islands of Galápagos during the 1930s. In 1975, it was discovered on an uninhabited island at a camping area used by scientists. *W. auropunctata* is a tiny ant which lives in small colonies containing several queens and has a high level of swarming activity by which it disperses easily over large areas. The ants are highly aggressive and do not tolerate other invertebrates in their immediate vicinity. Areas infested by them undergo the loss of many endemic and native invertebrate species. This is especially true in the transition zone on Santa Cruz where they are most abundant. However, since there was never a complete inventory of invertebrate species before the *W. auropunctata* invasion, the extent of their impact cannot be quantified. Few spider species are able to coexist with *W. auropunctata*. In parts of the transition zone not heavily infested with the ants we encountered 16 spider species, whereas in strongly infested areas of the zone we found only two tiny oonopid spiders and one ochyroceratid spider, all of which were possibly introduced with the ants.

By the time people realized what kind of damage was being caused by *W. auropunctata*, it was too late; whole areas were literally covered with the ants and it is likely that we will never be able to eradicate the species without inflicting serious damage to other native invertebrates.

Introduced invertebrates are in general extremely difficult to eradicate once they have established themselves. Generally they are small, they hide in tiny cracks and holes and are thus easily overlooked. They can easily be transported from one island to another by means of cargo ship or tourist or fishing boat. Once on land they can as easily be transported by man over the whole island. Many also have the ability to fly and can colonize nearby islands on their own. Only one gravid female is needed to start an entire population, for invertebrates can breed at high rates and inbreeding does not seem to effect population quality.

Introduced invertebrates tend to be extremely difficult to eradicate in part because they are hard to trace; they are noiseless (or their sounds resemble

that of the native species and it takes an expert to tell the difference), they don't leave footprints, they tend to disappear into places difficult to penetrate by man and they are not always very visible when flying. By the time they become a nuisance they usually have reached high population densities and are beginning to disperse. By then it is too late to intervene without drastic methods that may cause even more harm to the native invertebrate fauna.

So, what eradication methods can be used? Each group or species requires a different eradication method. One possibility is biological control. For this, a biological enemy is needed to control or eradicate the pest species without becoming a nuisance species itself. This method opens new perspectives but needs a thorough initial study of the ecology of both the pest species and the biological control species which is, of course, yet another introduced species and therefore a potential problem species.

An example of a recent introduction is the *Polistes versicolor* wasp. This introduction apparently occurred in 1988 during a shipment of bananas and other fruit from mainland Ecuador to Floreana Island. The wasp has since spread over all of the archipelago. Not only is the sting very painful and sometimes causes fever, but *P. versicolor* may be having a significant negative impact on the Galápagos ecosystem by competing with native fauna. From an unpublished report prepared by Jhon Heraty et al., the major prey item of *P. versicolor* might be caterpillars, a major dietary item of many birds and reptiles and of *Calosoma* beetles. The danger exists that a severe disruption of caterpillars might have disastrous effects on these various populations.

*Polistes* wasps are not regarded on the mainland as pest animals in normal numbers, but as an introduced species on the remote islands of Galápagos things may be different. For this reason the wasps are being observed closely and anxiously by entomologists at CDRS under the supervision of Sandra Abedrabbo, and eradication possibilities are being discussed. For example, *Polistes* have many parasites (over 40 species are known) and one of them may possibly be useful as a biological control agent.

Other recent introductions of exotic invertebrates have not illicited much attention because unlike *W.*

*auropunctata* and *P. versicolor*, they do not sting and have not come directly into contact with humans. Only scientists working in Galápagos generally encounter them. But with these "hidden" introductions too, native or endemic species may be adversely affected. There are now two Cicindelid beetles living in sympatry in lagoons and salt marshes along the coast of Santa Cruz (Desender et al., 1992b). One species, *Cicindela galapagoensis*, is endemic and well spread over the archipelago. The second species, *Cicindela trifasciata*, is known from the western part of Central and South America. Our data on *C. trifasciata* show that it has only been collected since 1983, even though the habitat it occupies on Santa Cruz has been searched on many earlier occasions. The first individual was collected at the end of the 1982/1983 El Niño event. The recent population growth and relative abundance of *C. trifasciata* in the Bahia Tortuga lagoon area compared to that of the endemic *C. galapagoensis* shows it has become very abundant in a short time span. The introduced species may be displacing the endemic species. The restricted occurrence of *C. trifasciata* on Santa Cruz suggests that it was introduced by man. However, the importance of the El Niño events must be emphasized in this particular colonization. El Niño events may increase the number of possible colonizations, primarily by an increase in vegetation rafts from the mainland forming and reaching Galápagos due to increased rainfall on the mainland, but also because climatic conditions are more favorable for establishment of newly arrived species in the usually harsh environments of Galápagos. Such events may well have helped during the first steps in the adaptive radiation and evolution of many invertebrates of the archipelago.

A second hidden introduction involves the spider *Anyphaenoides octodentata*. *A. pacifica* is widespread over the Galápagos archipelago, from the pampa down to the littoral zone. The vicinity around CDRS is always emphasized during each collecting campaign. The second to last collection done in this area in 1989 by Peck revealed the presence of only the native species *A. pacifica*. Our last collections (by Peck and myself) in 1991 revealed the sudden presence of a second congeneric species, *A. octodentata* (11 specimens) living sympatrically with the

former species. This species has a wide continental distribution from Venezuela to Perú.

An interesting note about the species is that it was discovered for the first time in 1971 in the German seaport of Hamburg in a load of Ecuadorian bananas. Has this species been accidentally introduced to Galápagos in a shipment of bananas or other fruit or vegetables from the mainland? It certainly appears so, as *A. octodentata* appeared suddenly in the vicinity of Puerto Ayora where most of the goods shipped from the mainland to Santa Cruz are unloaded. A specimen was also found at Puerto Baquerizo Moreno, the shipping port for San Cristóbal.

It seems clear that introductions are occurring through transport of goods by boat and by plane from mainland Ecuador. Food products are especially likely to carry unwanted invertebrates. The nonchalance with which the unloading of merchandise is conducted indicates a need for more controlled supervision of docking activities. All goods should be carefully controlled and if necessary treated in an adequate way to insure that no living animals are transported along with them. As long as there is no better control of the the import goods to the islands there remains the very real danger of continuing to introduce potentially harmful plants and animals to the islands.

Tourism also plays a negative role in affects on the local fauna and flora. Boats travelling between islands increases the risk of genetic pollution between the well established isolated populations of closely related taxa. Insects are frequently attracted to the lights of tourist and fishing boats anchored near shore at night. Boats often travel between islands at night or in the predawn hours carrying these insects to a new location. A recent study revealed that flying insects are much less attracted to yellow light than white light. The use of yellow lights should be obligatory on every boat navigating in the Galápagos waters.

Finally, man is not only affecting the faunal composition of the islands by introducing animals by design or accident, but also by altering the natural landscape. One example is the exploitation of the most fertile zone of Santa Cruz, the *Scalesia* zone, for agricultural activities and livestock. To end this article I give a specific example of the impact of

human-introduced arthropods on the native fauna with a synopsis of a comparative study on the spider community of different vegetation zones on Santa Cruz (Baert et al., 1991). Our data reveal 22 species for the agricultural zone (outside Park boundaries) and 20 species for the remaining *Scalesia* area near Los Gemelos. The transformation of the original *Scalesia* zone into the agricultural zone resulted in a slight quantitative enrichment (with only two additional species), but also in a qualitative impoverishment of the original *Scalesia* fauna. For instance, seven endemic species and two native species disappeared and were replaced by three endemic species originating from the lower arid zones, by one native species, four man-dependent species and by two introduced species, the man-dependent and introduced species obviously having a lower value for nature conservation and the maintenance of biological diversity in Galápagos.

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