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Forest affinity of Belgian terrestrial isopods (Isopoda: Oniscidea)

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Abstract

Categorizing species with respect to their affinity to forest ecosystems can help to assess forest habitat quality and support scientifically based decision-making for management. Recently, a set of forest affinity assessments was published covering 25% of the German fauna. Unfortunately, terrestrial isopods were not included, despite their importance for forest functioning. We applied the methodology of the German lists, which is also relevant for Belgium, to assess the forest affinity of the terrestrial isopods of Belgium, distinguishing between the Atlantic region and the Continental region of the country i.e. respectively north and south of the rivers Sambre and Meuse. All 36 Belgian terrestrial isopod species could be assessed of which 62% can be found in forests in the Atlantic region and 77% in the Continental region. Of these, 25% and 43% have forest as their main habitat in the Atlantic and Continental region respectively. We conclude that terrestrial isopods, compared to other forest associated taxa, contain higher proportions of highly sensitive and rare closed-forest related species, and therefore constitute important input to multi-taxa forest surveys. The assessment of forest affinity in this paper can be used in large parts of Western Europe.

Keywords: Belgium, habitat, forest characterization, indicator species, woodlice

Samenvatting

Het categoriseren van soorten met betrekking tot hun affiniteit met bosecosystemen kan helpen bij het beoordelen van de kwaliteit van boshabitats en het ondersteunen van wetenschappelijk onderbouwde besluitvorming voor beheer. Onlangs is een reeks bosaffiniteitsbeoordelingen gepubliceerd die 25% van de Duitse fauna bestrijken. Helaas werden terrestrische isopoden niet opgenomen, ondanks hun belang voor het functioneren van bossen. We hebben de methodologie van de Duitse lijsten toegepast, die ook relevant is voor België, om de bosaffiniteit van de terrestrische isopoden van België te beoordelen, waarbij we onderscheid maken tussen het Atlantische gebied en het continentale gebied van het land, dwz respectievelijk ten noorden en ten zuiden van de Samber en Maas. Alle 36 Belgische terrestrische isopodensoorten konden worden beoordeeld, waarvan 62% voorkomt in bossen in het Atlantische gebied en 77% in het continentale gebied. Hiervan heeft 25% en 43% bos als belangrijkste habitat in respectievelijk de Atlantische en continentale regio. We concluderen dat terrestrische isopoden, in vergelijking met andere bosgerelateerde taxa, hogere hoeveelheden zeer gevoelige en zeldzame gesloten bosgerelateerde soorten bevatten en daarom een belangrijke input vormen voor multi-taxa forest onderzoeken. De beoordeling van bosaffiniteit in dit document kan in grote delen van West-Europa worden gebruikt.

Résumé

Catégoriser les espèces en fonction de leur affinité avec les écosystèmes forestiers peut aider à évaluer la qualité des habitats et à mener une gestion mieux adaptée car fondée sur des données scientifiques. Récemment, une série de groupes taxonomiques a fait l'objet d'une telle catégorisation en Allemagne et cette évaluation couvre 25 % de la faune allemande. Malheureusement, les isopodes terrestres n'ont pas été pris en compte, malgré leur importance dans les écosystèmes forestiers. Nous avons appliqué la méthodologie utilisée pour constituer les évaluations allemandes, également pertinente pour la Belgique, afin d'évaluer l'affinité forestière des isopodes terrestres de Belgique, en distinguant la région atlantique et la région continentale du pays, c'est-à-dire respectivement au nord et au sud du sillon Sambre et Meuse. Les 36 espèces d'isopodes terrestres belges ont pu être catégorisées, 62% se trouvant dans les forêts de la région atlantique et 77% dans la région continentale. Parmi ceux-ci, 25 % ont la forêt comme principal habitat dans la région atlantique et 43 % dans la continentale. Nous concluons que les isopodes terrestres, comparativement à d'autres taxons associés aux forêts, contiennent des proportions plus élevées d'espèces très sensibles et rares liées aux forêts fermées, et constituent donc un élément important pour les études de taxons multiforestiers. L'évaluation de l'affinité des forêts présentée dans ce document peut être utilisée dans une grande partie de l'Europe occidentale.

Introduction

Forests worldwide are under severe pressure because of forest fragmentation, land conversion, invasive species, climate change and many more. The need to characterize forests and its associated biodiversity is therefore more urgent than ever. Because of their complex structure, forests are important as habitat for multiple taxa. Identifying organisms that can function as indicators of well-developed forest habitat can therefore aid nature conservation in determining the state and conservation importance of forest habitat. Species lists alone are insufficient to fully evaluate this value, if not accompanied by ecological information on habitat requirements of species. In this context, it is important to know to what extent species are related to specific aspects of the forest habitat, or may also or more often occur in clearings or open countryside. SCHMIDT *et al.* (2011) have done pioneer work by compiling a list of vascular plants, ferns, mosses and lichens based on their cover and occurrence in forest ecosystems in Germany. They classified almost 3,000 species on how strongly they are bound to forest habitat. This list has been widely used for forest research and forest characterization, and was recently extended to cover all areas of western continental Europe (HEINKEN *et al.* 2019). Both publications allocate all covered species to different forest affinity classes, although there are small differences between both publications.

In analogy with the species list published by SCHMIDT *et al.* (2011), similar lists were published by DOROW *et al.* (2019) assessing the forest affinity of nine animal groups. They assessed 25% of all species known in Germany and covered ecologically relatively well-known groups like birds, spiders and macro-Lepidoptera (butterflies and moths) but also an array of less and poorly known taxa like earthworms, beetles, harvestmen, pseudoscorpions, true bugs and Aculeata (ants, bees and wasps). They assessed the forest affinity of all species within the group, including forest species, as well as open-habitat species and ubiquists. The different classes used by DOROW *et al.* (2019) for fauna groups are presented in Table 1. For most taxa, there is a strong overlap between German and Belgian species lists, making the list of DOROW *et al.* (2019) very useful to assess Belgian forest diversity as well.

Unfortunately, terrestrial isopods (Isopoda: Oniscidea) are not covered in this list despite their often high abundances and functional importance in forests. Forests are a buffered habitat for organisms that are highly dependent on stable moist condition like terrestrial isopods. Being macro-detritivores, i.e. eating dead organic material, terrestrial isopods perform a crucial step for nutrient cycling in forest ecosystems. Assessing their forest affinity can help to better implement terrestrial isopods as ecological indicators for forest habitat. The recent publication of a new ecological atlas of the Belgian terrestrial isopods covering all of Belgium (DE SMEDT *et al.*, 2020), provided the necessary data to evaluate the forest affinity of all Belgian species according to the assessment methodology of DOROW *et al.* (2019).

Material and methods

The classification in forest affinity classes of Belgian terrestrial isopods was based on expert assessment, relying on the existent data on occurrence and ecology of terrestrial isopods gathered in the ecological atlas by DE SMEDT *et al.* (2020). For this atlas, 369 out of 373 squares (99%) of the UTM 10 x 10 km grid in Belgium were surveyed between 2014 and 2020. It was aimed to investigate three key terrestrial isopod habitats in every 10 x 10 km square being forest habitat, open habitat and anthropogenic habitat. Forest habitat was investigated in 321 squares (86%). If present, forest habitat consisted of ancient forest. This includes forest that was continuously present since the Ferraris map (around 1775). If no ancient forest was present, we visited young forest or forested areas along small streams. We also considered natural forest gaps, clear cuts, forest roads and forest waters as forest habitat. The open habitat consisted of riversides, wetlands, roadside verges, field margins, coastal habitat etc. Anthropogenic habitat was strongly transformed habitat like city centers, graveyards, farmyards, old walls, compost heaps and gardens. Our sampling of graveyards is an important difference with DOROW *et al.* (2019) since we did not consider them as forest. Many graveyards across the country are lacking trees or any vegetation at all and can therefore not be considered as forest habitat. This is often different in Germany.

Using these data records, ecological background based on field observations (DE SMEDT *et al.* 2020) and literature knowledge (DE SMEDT *et al.* 2018c), we were able to consistently evaluate all 36 Belgian terrestrial isopod species and allocate them to one of the forest association categories used by DOROW *et al.* (2019) (Table 1).

Table 1. Forest affinity categories according to DOROW *et al.* (2019).

w: strong affinity to forest habitat, without known preference for light or closed forest
wg: mainly found in forests, with strong affinity to closed forest habitat
wl: mainly found in forests, with strong affinity to open forests, forest edges or glades
m: occurring in both open landscapes and forest habitat, but without preference for forest habitats
mm: occurring equally in open landscapes and forest habitats
mo: strong affinity to open landscapes, but also regularly occurring in forests, at forest edges or in glades
o: only occurring in open landscapes or other habitats without forest cover like caves or buildings
u: unknown

Belgium is a small but topographically heterogeneous country, with a small shoreline and a flat Atlantic region with low forest cover and high forest fragmentation in the northern part and a continental hilly landscape with higher forest cover in the east and south of the country. Therefore, we assigned separate categories to the species for the Atlantic region of Belgium and the Continental region of Belgium (ROEKAERTS, 2002), corresponding to the north and

south of the rivers Sambre and Meuse respectively (Fig. 1). We will further use the terms Atlantic region and Continental region.

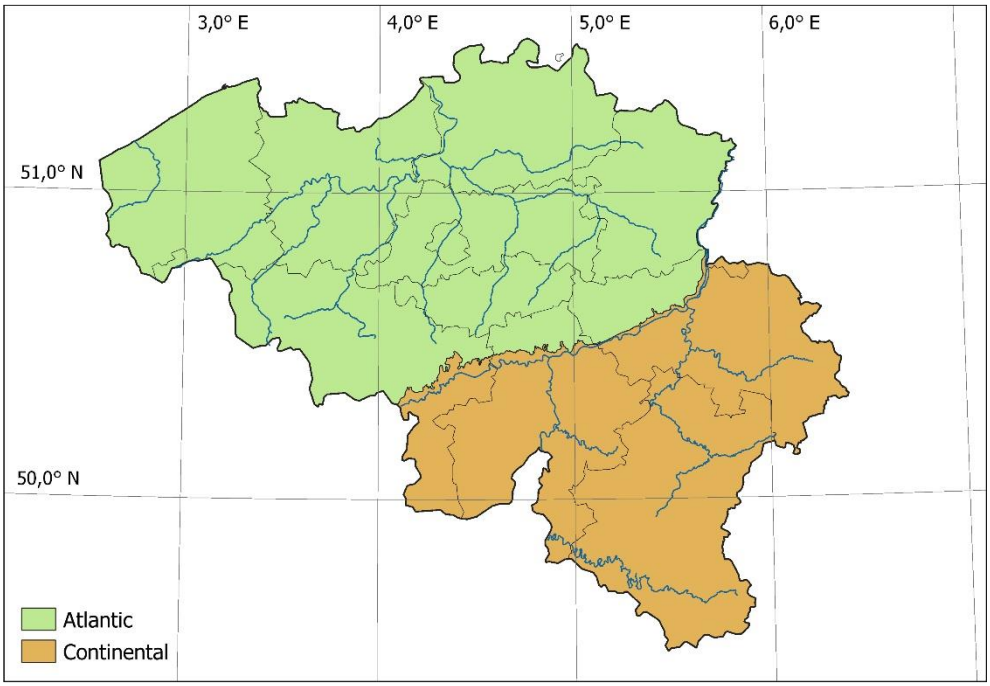

Fig. 1. Map showing the Atlantic region (Green) and the Continental (Orange) region of Belgium, corresponding with respectively north and south of the rivers Sambre and Meuse.

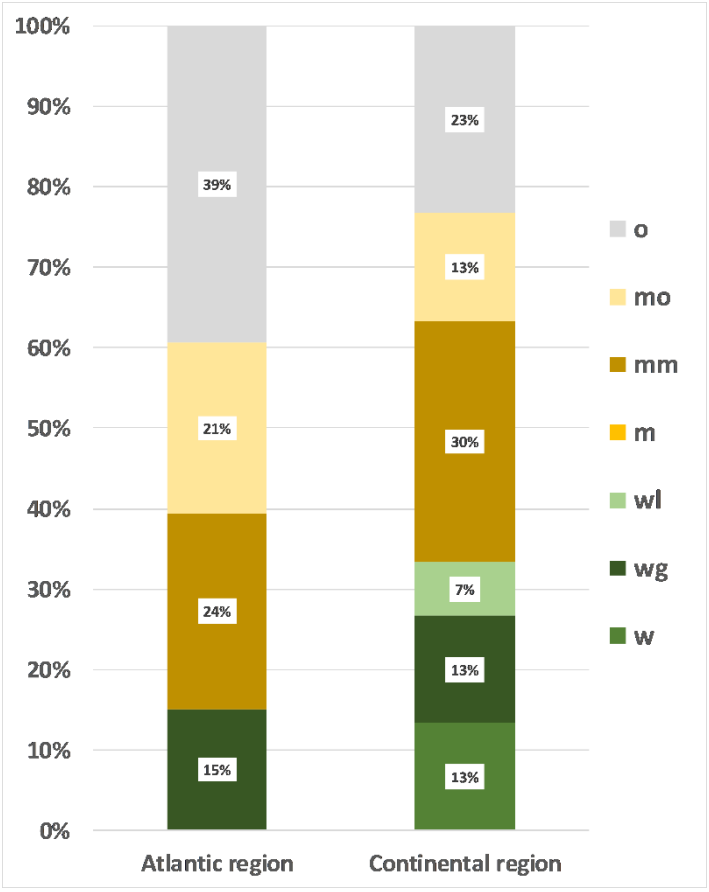

Fig. 2. Percentage of species assigned to the different forest affinity categories for the Atlantic and the Continental region of Belgium.

The List

In the Atlantic region, 33 species of terrestrial isopods are recorded and evaluated. In the Continental region 30 species are recorded and evaluated (Table 2). All species could be evaluated and therefore no species are classified as unknown ("u"). In the Atlantic region, 62% of the species are regularly found in forest habitat of which 25% have a strong affinity to forest (w, wg and wl) (15% of the total species pool; Fig. 2). In the Continental region, 77% of the species are regularly found in forest habitat of which 43% have a strong affinity to forest (w, wg and wl) (33% of the total species pool; Fig. 2). In the Atlantic region, 24% of the species are equally found in forest and open areas ("mm") (Fig. 2), while this is 30% in the Continental region (Fig. 2). Note that also the category "m" does not occur in the list for the Belgian terrestrial isopods and the category "w" and "wl" does additionally not occur in the Atlantic region.

Table 2. Forest affinity of terrestrial isopod species in the Atlantic region of Belgium and in the Continental region of Belgium. Forest affinity categories according to DOROW *et al.* (2019) (see Table 1). "/" indicates that the species is not present.

	Scientific name	Atlantic region	Continental region
	Ligiidae		
1	*Ligia oceanica* (Linnaeus, 1767)	o	/
2	*Ligidium hypnorum* (Cuvier, 1792)	wg	wg
	Trichoniscidae		
3	*Androniscus dentiger* Verhoeff, 1908	o	mo
4	*Haplophthalmus danicus* Budde-Lund, 1880	mm	mm
5	*Haplophthalmus mengii* (Zaddach, 1844)	mo	w
6	*Haplophthalmus montivagus* Verhoeff, 1941	mm	mm
7	*Hyloniscus riparius* (C. Koch, 1838)	mo	mm
8	*Metatrichoniscoides leydigii* (Weber, 1880)	o	/
9	*Miktoniscus patiencei* Vandel, 1946	o	/
10	*Trichoniscoides albidus* (Budde-Lund, 1880)	mo	w
11	*Trichoniscoides helveticus* (Carl, 1908)	mm	mm
12	*Trichoniscoides sarsi* Patience, 1908	mo	o
13	*Trichoniscus alemannicus* Verhoeff, 1917	/	wl
14	*Trichoniscus provisorius* Racovitza, 1908	mm	mm
15	*Trichoniscus pusillus* Brandt, 1833	mm	mm
16	*Trichoniscus pygmaeus* Sars, 1898	mo	mo
	Oniscidae		
17	*Oniscus asellus* Linnaeus, 1758	mm	mm
	Philosciidae		
18	*Philoscia affinis* Verhoeff, 1908	wg	wg
19	*Philoscia muscorum* (Scopoli, 1763)	mm	mm
	Platyarthridae		
20	*Platyarthrus hoffmannseggii* Brandt, 1833	o	o

	Scientific name	Atlantic region	Continental region
	Armadillidiidae		
21	*Armadillidium album* Dollfus, 1877	o	/
22	*Armadillidium nasatum* Budde-Lund, 1885	o	o
23	*Armadillidium opacum* (C. Koch, 1841)	wg	w
24	*Armadillidium pictum* Brandt, 1833	wg	wg
25	*Armadillidium pulchellum* (Zencker, 1798)	wg	wg
26	*Armadillidium vulgare* (Latreille, 1804)	mo	mo
27	*Eluma caelata* (Miers, 1877)	o	/
	Cylisticidae		
28	*Cylisticus convexus* (De Geer, 1778)	o	o
	Porcellionidae		
29	*Porcellio dilatatus* Brandt, 1833	o	o
30	*Porcellio laevis* Latreille, 1804	o	/
31	*Porcellio monticola* Lereboullet, 1853	/	wl
32	*Porcellio scaber* Latreille, 1804	mm	mm
33	*Porcellio spinicornis* Say, 1818	o	o
34	*Porcellionides pruinosus* (Brandt, 1833)	o	o
	Trachelipodidae		
35	*Porcellium conspersum* (C. Koch, 1841)	/	w
36	*Trachelipus rathkii* (Brandt, 1833)	mo	mo

Discussion

We assessed the forest affinity of all native terrestrial isopods in Belgium, applying the same methodology as in DOROW *et al.* (2019). This assessment is based on relative incidence of species in specific habitat classes evaluated by expert judgement, not on statistical analysis (e.g. species indicator analysis). A statistical analysis on this data would require data collected in an even more standardized way difficult to obtain on such a large scale. However, ecological knowledge on this species group collected by woodlice specialists during numerous field surveys provide enough information to allow for a sound and reliable assessment of species (as deducted from DE SMEDT *et al.* 2020).

In the Atlantic region of Belgium, about two out of three species are frequently found in forest habitat and in the Continental region more than three out of four. This is comparable to the overall forest affinity of other taxa (DOROW *et al.*, 2019). A number of reasons can explain the difference between the Atlantic and the Continental region of the country. 1) The occurrence of four species that are bound to coastal conditions and therefore only found in the Atlantic region: *Ligia oceanica, Miktoniscus patiencei, Armadillidium album* and *Eluma caelata*. 2) The presence of two species, only occurring in the south of the country, that have a more southeastern distribution and are associated to open forest habitat: *Trichoniscus alemannicus* and *Porcellio monticola*. 3) Some small species appear to be more often found in anthropogenic habitat at the border of their distribution ranges and therefore less in forest e.g. *Androniscus dentiger* in the Atlantic region or *Trichoniscoides sarsi* in the Continental region. 4) Small

species like *Trichoniscoides albidus* and *Haplophthalmus danicus* are relatively rare in the Continental region and almost exclusively found in forests.

Fig. 3. Terrestrial isopod species strongly associated to closed and ancient forest habitat in Belgium. From left to right and from above to below: *Ligidium hypnorum, Philoscia affinis, Armadillidium pulchellum, A. pictum* and *A. opacum*. © Gert Arijs.

The share of 15–33% of terrestrial isopod species with a strong forest affinity ("w", "wg" and "wl") is also comparable to other species groups in DOROW *et al*. (2019), such as Lumbricidae, Aranae and Coleoptera. For Opiliones and Pseudoscorpiones, these shares are much higher (both groups between 55 and 60%). Both Opiliones and Pseudoscorpiones are strongly bound to humid conditions and live very much inside the litter layer, struggling to survive outside the stable and protective forest environment.

Remarkable however, is the relatively high share of terrestrial isopods strictly associated to closed-forest conditions ("wg"). While for most species groups in DOROW *et al.* (2019), this share was often less than 5%, this figure amounts to 13–15% for terrestrial isopods (respectively five and four species in the Atlantic and the Continental region). These species are *Ligidium hypnorum*, *Philiscia affinis*, *Armadillidium pictum*, *Armadilidium pulchellum* and for the Atlantic region also *Armadillidium opacum* (Fig. 3). *L. hypnorum* and *P. affinis* are sensitive to drought and therefore restricted and characteristic to the more damp conditions of closed interior forest (see e.g. DE SMEDT *et al.*, 2018a, b, 2019). The other three species are from the genus *Armadillidium* and rather drought resistant, however they can be considered as poor dispersers (low running speed: M.P. BERG unpublished data), and dispersal limitation could be the problem for these species. They are therefore probably good indicators for ancient wood rather then closed forest per se. This is mainly supported by their distribution in the Atlantic region of Belgium were they are restricted to isolated ancient forest patches (DE SMEDT & VANDEKERKHOVE, 2020). Except *L. hypnorum* (common across the whole country), they are all very rare in the Atlantic region, and rather common to rare in the Continental region (DE SMEDT *et al.*, 2020). These species can therefore be considered as important indicators of ancient forests with long continuity of moderate forest interventions (no large clearcuts or overexploitation). In this context terrestrial isopods may be considered as umbrella species for a wide range of late-successional forest species (including fungi, snails…) that also require this continuity and are more difficult to assess. Due to their wide range of habitat requirements, their large share of species strongly affiliated to ancient closed-canopy forests and their importance for ecological functioning due to their role in decomposition, terrestrial isopods can be assigned high indicative value for assessment of forest habitat quality, and should be more often included in in multi-taxa forest surveys.

Forest affinity assessments can be a valuable tool in this context. The list proposed in this paper is representative for a large part of Western Europe. The list for the Atlantic region of Belgium can be used for the Netherlands, the NW lowlands of Germany, the atlantic region of Denmark and the atlantic region of France (see HEINKEN *et al*. (2019) for delineation of the regions). The list for the Continental region of Belgium can be used for the continental region of France, Luxembourg, the uplands of Germany, the lowlands of NE Germany, the continental region of Denmark and the nemoral zone (extreme south) of Sweden.

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