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On distribution patterns of very rare Chilopoda and Diplopoda in Germany

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Abstract. During the last years the Working Group of German Speaking Myriapodologists accomplished a survey on German Chilopoda and Diplopoda. As one result of all compiled distribution data, 77 very rare (= not more than 30 occurrences at distinctive locations since 1990) native species could be identified. These rare species (14 chilopods, 63 diplopods) show four different general distribution types in terms of the distribution area in Germany and the entire distribution area: endemics (7), local in Germany/local in general (30 species), local in Germany/wide spread in general (27 species) and wide spread but patchy in Germany/wide spread in general (13 species). More than half (58%) of rare species are restricted to Southern Germany, a myriapod diversity hot spot in Germany. Other rare species are restricted to Eastern Germany and only a few species to Western Germany.

Key words. Myriapoda, rare species, distribution borders, German hot spots.

INTRODUCTION

The Working Group of German Speaking Myriapodologists started a survey of research on German Diplopoda and Chilopoda to document and evaluate the current degree of endangerment of the 201 species (61 chilopods, 140 diplopods) known for Germany for the so-called "Red Lists" (Voigtländer et al. 2011, Reip et al. in press, Decker et al. in press). The "Red Lists" are an important basis for conservation actions, environmental planning and assessments and are evaluated on distribution and population dynamics.

The first and most obvious criterion is a very low number of records of a species. Rare was determined by Reip et al. (2012) 30 or less occurrences since 1990 until the present date (2013). Reip et al. (2012) showed also that there are several factors, which determine the rarity of a species. Beside the subjective factors (e.g. regional intensity of individual collections, sampling methods) there are more important objective factors like the general distribution area and restrictions to specific environmental conditions (e.g. biotope type, micro habitat, soil, altitude, temperature). The increase of records during the last two decades had no appreciable influence on the formerly known size and borders of the distribution areas or characteristics (e.g. scattered, local) of rare species. The following analysis of distribution areas of all rare species in Germany will demonstrate this in more detail.

METHODS

The analysis of distribution area was made with the help of the database for distribution and ecology of soil organisms, called "Edaphobase" (Burkhardt et al. 2014), which is located in the Museum of Görlitz and available on-line: www.edaphobase.org. By a total of 8,040 distinctive localities (= occurrences) (Fig. 1) with 77,896 records (different biotope types or dates at the same locality) the rare species have 1,326 occurrences (Fig. 2) (thereof 1,001 occurrences of Diplopoda and 325 of Chilopoda) (Reip et al. 2012).

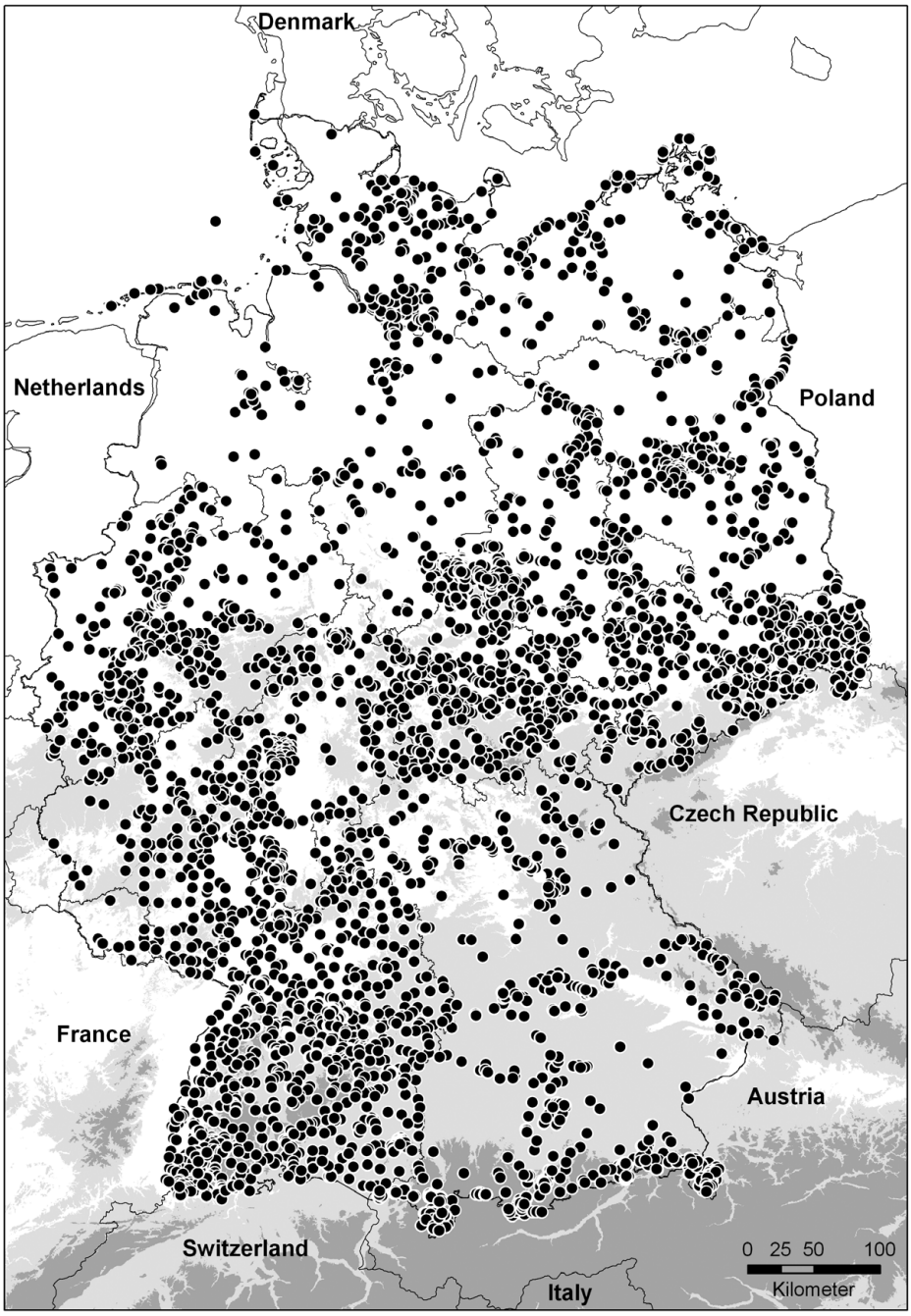

Fig. 1. Locations (records) of all myriapod species in Germany.

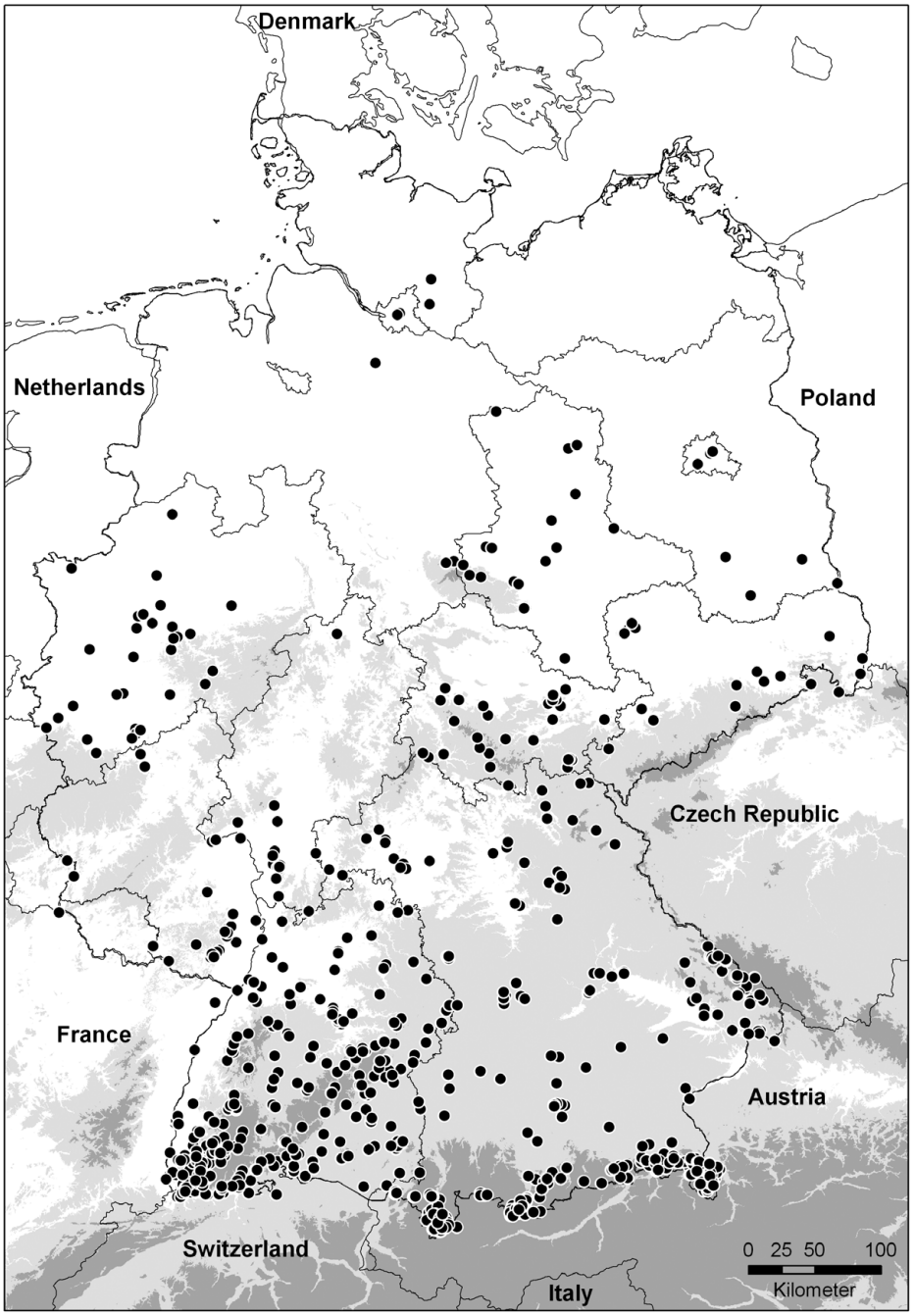

Fig. 2. Locations (records) of rare species in Germany.

According to Voigtländer at al. (2011) a species is defined as very rare, when there are no more than 30 records of this species since 1990 on different sites. Maps were created with ArcGIS (Version 10).

RESULTS

The 77 very rare species (14 chilopods, 63 diplopods) show distinct distribution patterns (Table 1).

Endemics

Seven myriapod species (1 chilopod, 6 diplopods) are known to be endemic in Germany. Therefore they need special attention and responsibility. Five of the six endemic diplopod species *Pyrgocyphosoma titianum*, *Rhymogona serrata*, *R. verhoeffi*, *R. wehrana* and *Xylophageuma vomrathi* are restricted to the South of Germany in Baden-Württemberg (Figs. 3–5). *Glomeris malmivaga* (Fig. 4) occurs beside Baden-Württemberg also locally in Western Bavaria. The only endemic centipede *Geophilus rhenanus* (Fig. 4) is known from two localities at the Rhine Valley. This

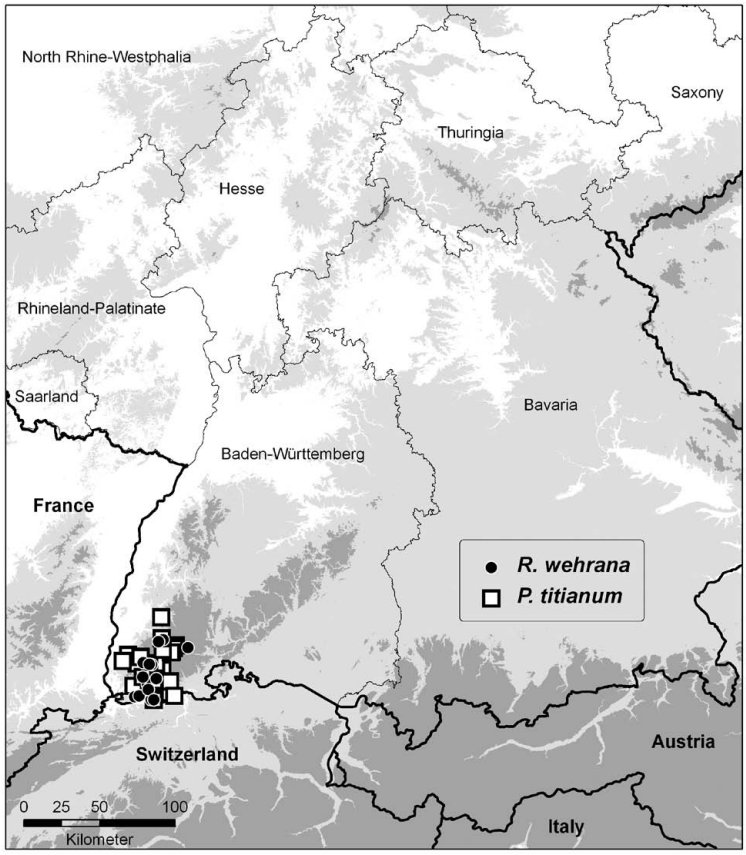

Fig. 3. Distribution of endemic species in Germany 1.

Table 1. Distribution of rare species (N=North, S=South, E=East, W=West, also for X in "X-part"); X = distribution border in X-part of Germany

species	X	detailed distribution border	main distribution area
endemics			
Geophilus rhenanus Verhoeff, 1895		–	Rhine Valley
Glomeris malmivaga Verhoeff, 1912		–	Swabian Alp
Pyrgocyphosoma titianum (Verhoeff, 1910)		–	SW Black Forest
Rhymogona wehrana (Verhoeff, 1910)		–	E Dinkelberg and SW Black Forest
Rhymogona verhoeffi (Bigler, 1913)		–	Black Forest and Neckar Valley
Rhymogona serrata (Bigler, 1912)		–	W Dinkelberg
Xylophageuma vomrathi Verhoeff, 1911		–	Middle and S Black Forst
local in Germany / local in General			
Allajulus grödensis (Attems, 1899)	S	N in Bavaria	Central Alps
Bergamosoma canestrinii (Fedrizzi, 1878)	S	N in Bavaria	Central Alps
Craspedosoma taurinorum Silvestri, 1898	S	N in Bavaria	Western Alps
Cylindroiulus zinalensis (Faes, 1902)	S	N in Bavaria	Central Alps
Dendromonomeron oribates (Latzel, 1884)	S	N in Bavaria	North Eastern Alps
Geophilus studeri Rothenbühler, 1899	S	N in Southern Germany	Western Alps
Glomeridella minima (Latzel, 1884)	S	NW in Bavaria	Eastern Alps
Glomeris helvetica (Verhoeff, 1894)	S	NE in Southern Germany	Western Alps
Glomeris transalpina Koch, 1836	S	N in Bavaria	Western Alps
Haasea germanica (Verhoeff, 1901)		–	Germany
Haasea norica (Verhoeff, 1913)	S	N in Bavaria	North Eastern Alps
Halleinosoma noricum Verhoeff, 1913	S	N in Bavaria	North Eastern Alps
Iulogona tirolensis (Verhoeff, 1894)	S	N in Bavaria	Central Alps
Leptoiulus alemannicus (Verhoeff, 1892)	S	N in Bavaria	Central Alps
Leptoiulus marcomannius Verhoeff, 1913	S	W in Bavaria	Bohemian Forest
Leptoiulus noricus Verhoeff, 1913	S	N in Bavaria	Central Alps
Leptoiulus saltuvagus (Verhoeff, 1898)	S	N in Bavaria	Central and Eastern Alps
Listrocheiritium cervinum Verhoeff, 1925	S	N in Bavaria	North Eastern Alps
Lithobius glacialis Verhoeff, 1913	S	N in Bavaria	Central Alps
Ochogona brentana (Verhoeff, 1928)	S	N in Bavaria	Southern and Central Alps
Ochogona regalis (Verhoeff, 1913)	S	N in Bavaria	North Eastern Alps
Ophyiulus major Bigler et Verhoeff, 1928	S	N in Bavaria	Central Alps
Ophyiulus nigrofuscus (Verhoeff, 1894)	S	N in Bavaria	Central Alps
Orthochordeumella fulva (Rothenbühler, 1899)	S	NE in Southern Germany	Northern Switzerland, Alsatia, Baden-Württemberg
Pachypodoiulus eurypus (Attems, 1895)		postglacial relict	North Eastern Alps
Propolydesmus helveticus (Verhoeff, 1894)	S	N in Southern Germany	Western Alps
Pseudocraspedosoma grypischium (Rothenbühler, 1900)	S	N in Bavaria	Central Alps
Pteridoiulus aspidiorum Verhoeff, 1913	S	N in Bavaria	North Eastern Alps
Rhymogona montivaga alemannica (Verhoeff, 1910)	S	N in Southern Germany	Alsatia, Baden-Württemberg
Rhymogona montivaga cervina (Verhoeff, 1910)	S	NE in South West Germany	Northern Switzerland, Vogese
local in Germany / widespread in general			
Atractosoma meridionale (Fanzago, 1876)	S	N in Bavaria	Alps
Brachychaeteuma bagnalli Verhoeff, 1911	W	SE in Germany	Northwest Europe
Craspedosoma rawlinsii alsaticum (Verhoeff, 1910)	S	E in SW Germany	Western Europe
Cylindroiulus arborum Verhoeff, 1928	E	W in Eastern Germany	Eastern (Central) Europe
Cylindroiulus boleti (Koch, 1847)	S	NW in Southern Germany	Southeast Europe
Cylindroiulus fulviceps (Latzel, 1884)	S	N in Bavaria	Central Alps
Cylindroiulus luridus (Koch, 1847)	S	N in Bavaria	Southeast Europe
Geophilus oligopus (Attems, 1895)	S	NW in Bavaria	Eastern Alps

Table 1. (continued)

species	X	detailed distribution border	main distribution area
Glomeris connexa Koch, 1847	S	NW in Southern Germany	Alps and South Europe
Haploporatia eremita (Verhoeff, 1909)	E	W in Eastern Germany	Eastern (Central) Europe
Harpolithobius anodus (Latzel, 1880)	S	N in Bavaria	Southeast Europe
Julus terrestris Linnaeus, 1758	E	NW in Germany	Eastern (Central) Europe
Leptoiulus kervillei Brölemann, 1896	W	alien species?	Western Europe
Leptoiulus montivagus (Latzel, 1884)	S	N in Southern Germany	Southern Central Europe
Leptoiulus trilobatus (Verhoeff, 1894)	E	W in Eastern Germany	Eastern Central Europe
Lithobius latro Meinert, 1872	S	N in Bavaria	Alps
Lithobius punctulatus Koch, 1847	S	N in Bavaria	(Mediterranean) Europe
Lithobius pygmaeus Latzel, 1880	S	N in Southern Germany	Alps
Mastigophorophyllon saxonicum Verhoeff, 1910	E	W in Eastern Germany	Eastern (Central) Europe
Megaphyllum sjaelandicum (Meinert, 1868)	E	W in Eastern Germany	Eastern (Central) Europe
Melogona transsilvanica (Verhoeff, 1897)	S	W in Bavaria	Eastern (Central) Europe
Ommatoiulus vilnensis Jawlowski, 1925	E	W in Eastern Germany	Eastern Europe
Polydesmus monticola Latzel, 1884	S	N in Bavaria	Central- and Eastern Alps
Schendyla tyrolensis (Meinert, 1870)	S	N in Bavaria	Southeast Europe
Trachysphaera costata (Waga, 1857)		NW in Germany	South Eastern Europe
Trachysphaera gibbula (Latzel, 1884)	S	NW in Bavaria	Eastern (Central) Europe
Trachysphaera schmidtii Heller, 1858	S	NW in Bavaria	Southeast Europe
widespread in Germany / widespread in general			
Archiboreoiulus pallidus (Brade-Birks, 1920)		–	Europe
Brachychaeteuma bradeae (Brölemann et Brade-Birks, 1917)		–	Northwestern+Central Europe
Geoglomeris subterranea Verhoeff, 1908	S	NE in Germany	Western Europe
*Geophilus carpophagus*Leach, 1817		–	Europe
Geophilus proximus Koch, 1847	N	S in Germany	Northern Europe
Haasea flavescens (Latzel, 1884)	E	N in Eastern Germany	Alps, Bohemian Forest
Leptoiulus bertkaui (Verhoeff, 1896)		–	SW Germany
Leptoiulus cibdellus (Chamberlin, 1921)	E	W in Saxony-Anhalt	Eastern (Central) Europe
Lithobius lapidicola Meinert, 1872		alien species ??	Europe
Lithobius subtilis Latzel, 1880	W	NE in Germany	Central Europe
Ommatoiulus rutilans (Koch, 1847)	W	NE in Western Germany	West Mediterranean
Pachymerium ferrugineum (Koch, 1835)		–	Europe
Propolydesmus germanicus (Verhoeff, 1896)		N in Germany	Western (Central) Europe

species was recently separated from *Geophilus alpinus* Meinert, 1870 (Spelda 2005) and could be expected also on the French side of the Rhine.

Distribution: local in Germany / local in general

Thirty species (2 chilopods, 28 diplopods) show a restricted distribution area in Germany and have also a small distribution in general (examples see Fig. 6). Southern Germany with 28 species shows the highest number of very rare species, often with very small distribution areas. Nearly all of these species are endemic to the Alps which have their northern distribution border in Southern Germany. Exceptions are *Orthochordeumella fulva* (Fig. 6), *Rhymogona montivaga alemannica* and *R. montivaga cervina* which occur in Northern Switzerland and Alsace as well as *Leptoiulus marcomannius* which is distributed in the Bohemian/Bavarian forest. Another distribution pattern shows *Haasea germanica* (Fig. 6) which is restricted to Thuringia, to the Bavarian Forest, to some spots in Saxony and to the adjacent Czech Republic. *Pachypodoiulus eurypus*, a species

from the Northeastern Alps, has some small populations in Bavaria and Saxony which seem to be glacial relicts (Fig. 6).

Distribution: local in Germany / widespread in general

Twenty-seven rare species (21 chilopods, 6 diplopods) are limited to a small area in Germany, but are wide spread in Europe (examples see Fig. 7). It is interesting that 59% of these (16 species) have a distribution border in Germany. The majority of these species are widely spread in the Alps or Southeastern Europe with their northern distribution in Southern Germany, especially in the Allgäu and Berchtesgadener Land in Bavaria. Some species, *Cylindroiulus luridus* (Fig. 7), *C. boleti* or *Glomeris connexa* also reach Baden-Württemberg. Attention has to be paid on *G. connexa*, because the distribution area must be new defined after clarification of the name confusion with *G. tetrasticha* (Hoess & Scholl 2000). Only few Western European species (*Brachychaeteuma bagnalli* (Fig. 7), *Leptoiulus kervillei* Brölemann, 1896) have their eastern distribution border in Western Germany, whereas seven species common in Eastern (Central) Europe expand into Eastern Germany.

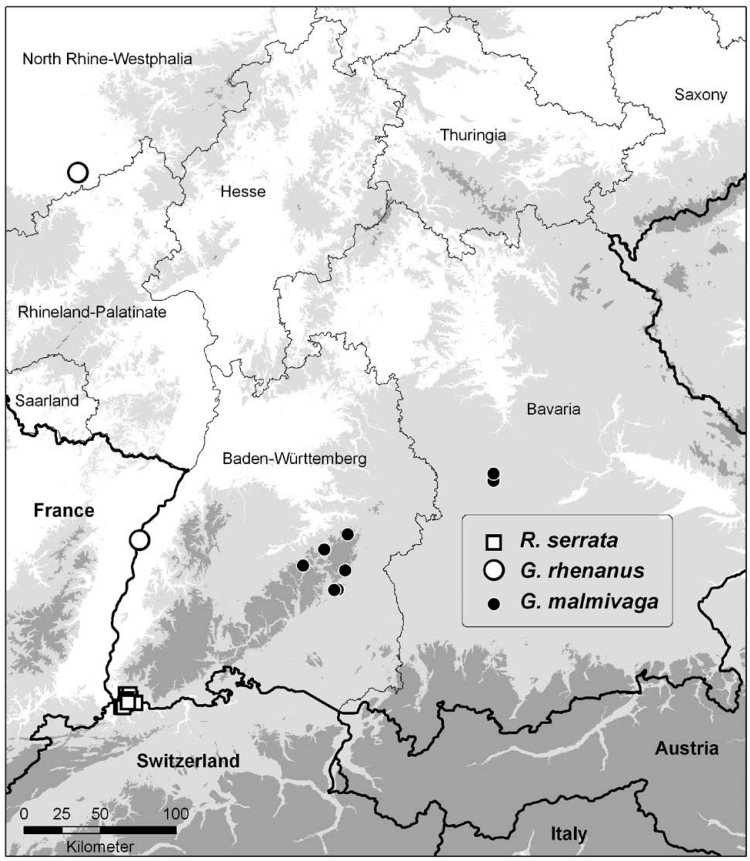

Fig. 4. Distribution of endemic species in Germany 2.

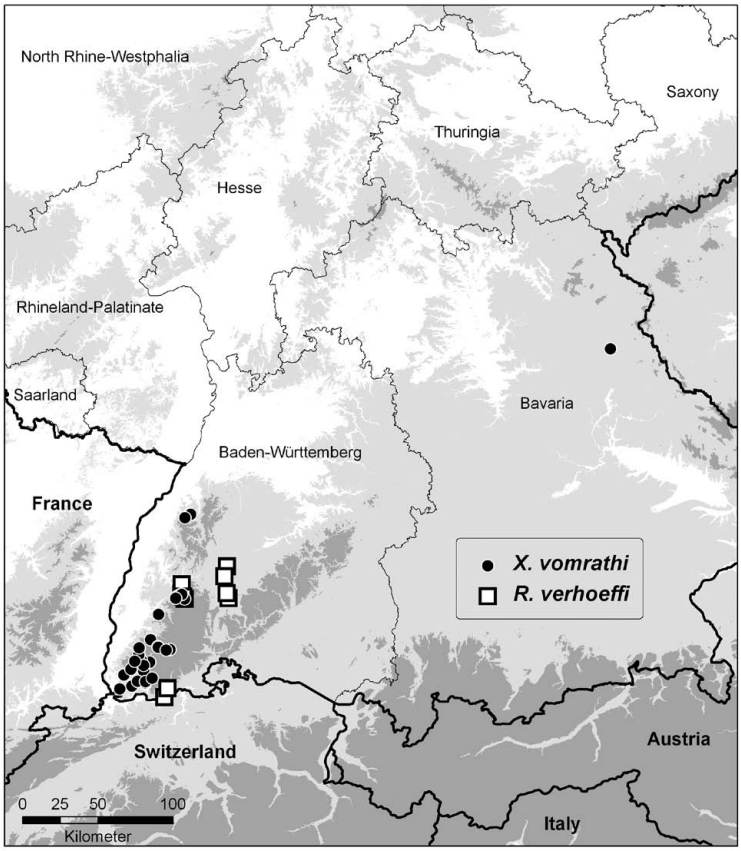

Fig. 5. Distribution of endemic species in Germany 3.

Distribution: widespread but patchy in Germany / widespread in general

This group consists of 13 (5 chilopods, 8 diplopods) species which are widely but patchy spread in Germany and also have a large distribution area in Europe (examples see Fig. 8). This group shows a very heterogenous mix of species.

Pachymerium ferrugineum, *Geophilus carpophagus*, and *G. proximus* are known from nearly whole Europe and also introduced to several countries and islands outside Europe. While *P. ferrugineum* was found scattered in whole Germany, especially in bogs, sedge swamps, alder swamps forests and contrary also mesoxeric meadows and other dry habitats. *G. carpophagus* is more common in Northern Germany and often found in urban areas, especially buildings. Current records of *G. proximus* are only known from Northern and Central Germany from moist forests.

Five species (*Propolydesmus germanicus*, *Haasea flavescens*, *Geoglomeris subterranea*, *Leptoiulus bertkaui*, *L. cibdellus*; see Fig. 8) show quite clear distribution areas throughout Europe. *P. germanicus* and *G. subterranea* are tiny species that probably were overlooked in the past not using adequate sample methods, e.g. (deep) soil sampling. *L. cibdellus* is known from Northeastern

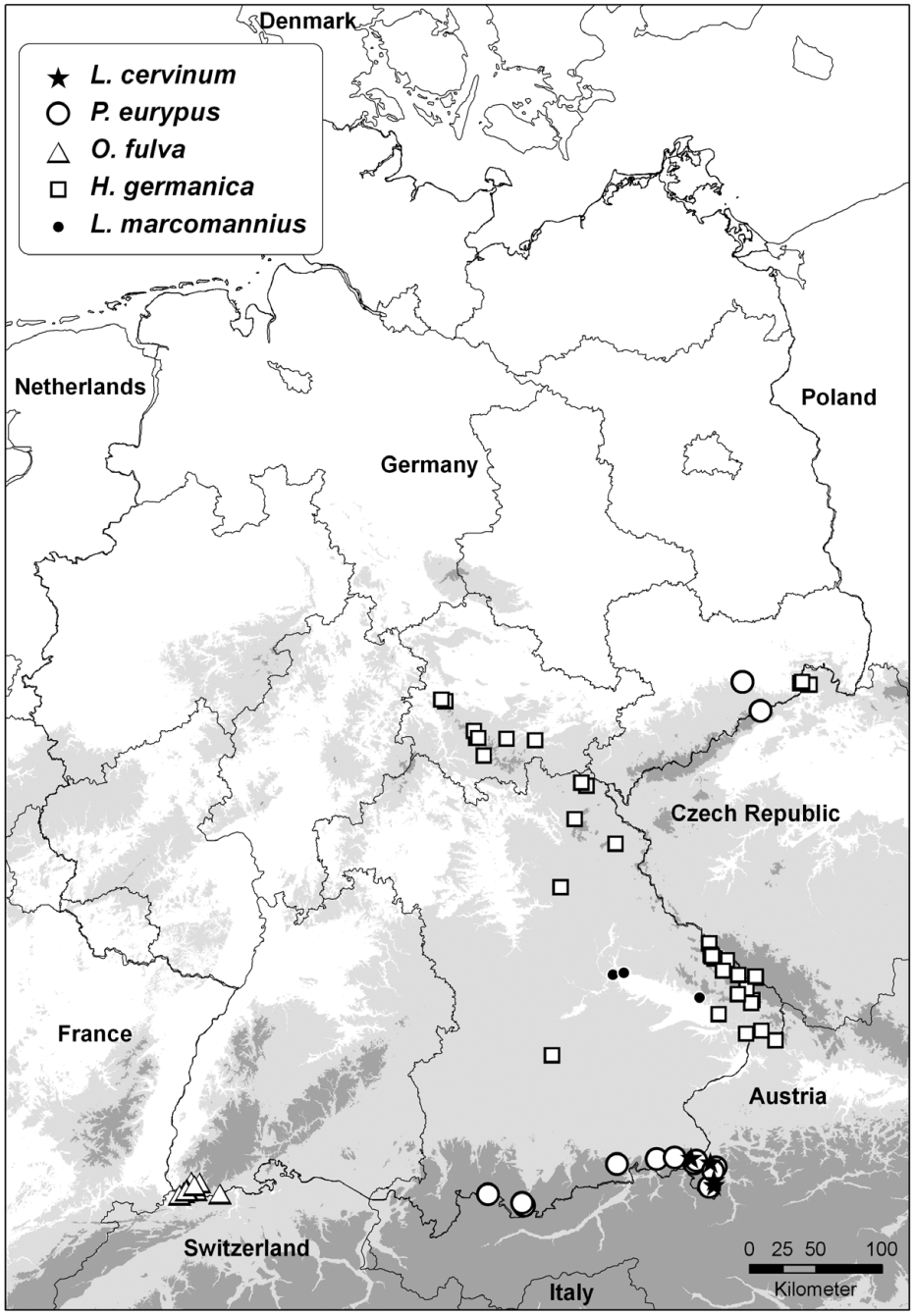

Fig. 6. Examples for the distribution type local in Germany / local in general.

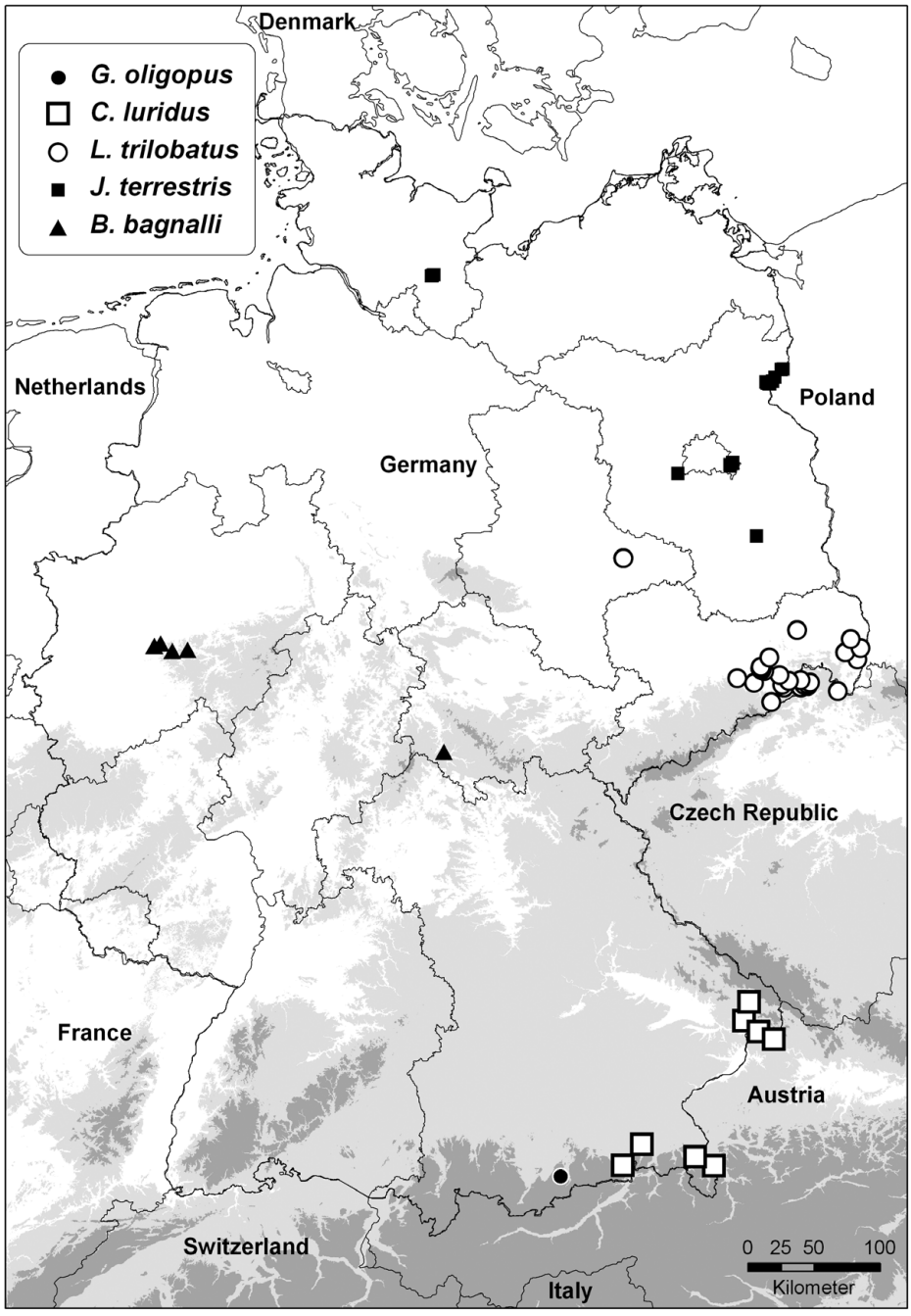

Fig. 7. Examples for the distribution type local in Germany / widespread in general.

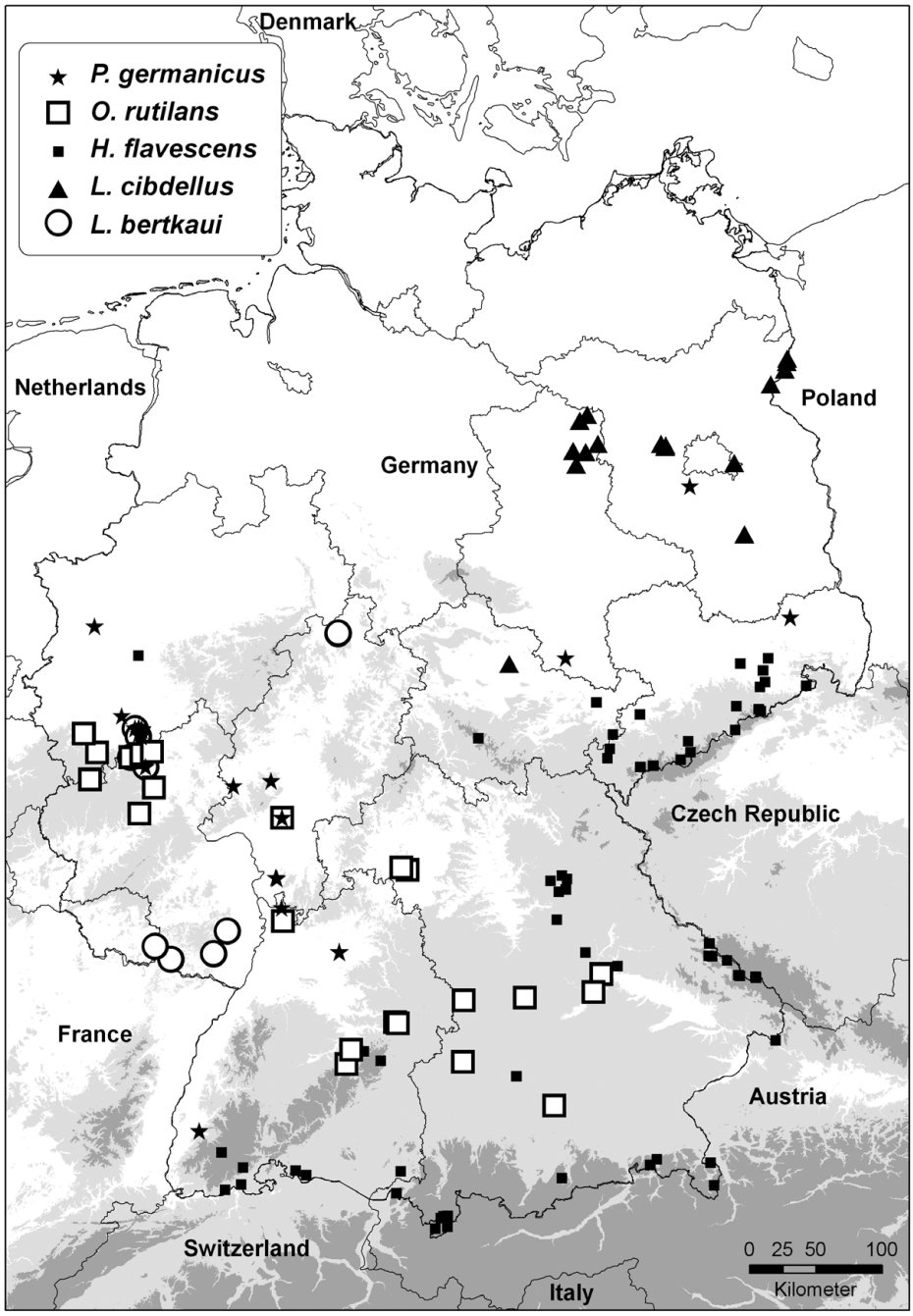

Fig. 8. Examples for the distribution type widespread but patchy in Germany / widespread in general.

Germany, the area with lowest collecting frequency in Germany and is probably more common in that area as known today. The main distribution area of *L. bertkaui* is Southwestern Germany and also adjacent areas of France and Switzerland.

Another five species (*Archiboreoiulus pallidus*, *Brachychaeteuma bradeae*, *Lithobius lapidicola*, *L. subtilis*, *Ommatoiulus rutilans*; see Fig. 8) show tendencies to prefer cultivated landscape and may be old alien species. There was an increase of records throughout Germany of the small and hard to differentiate lithobiids *L. lapidicola*/*subtilis*.

Alien species

The following 20 rare species are not native to the German fauna or assumed to be alien species by the authors. These species are restricted to urban areas or highly anthropogenic influenced habitats. Therefore, they were not used for the distributional analysis: *Anamastigona pulchella* (Silvestri, 1894); *Boreoiulus tenuis* (Bigler, 1913); *Brachychateuma melanops* Brade-Birks & Brade-Birks, 1918; *Brachyiulus lusitanus* (Verhoeff, 1898); *Cryptops anomalans* Newport, 1844; *Cylindroiulus parisiorum* (Brölemann & Verhoeff, 1896); *C. salicivorus* Verhoeff, 1908; *C. truncorum* (Silvestri, 1896); *C. vulnerarius* (Berlese, 1888); *Geophilus osquidatum* Brölemann, 1909; *Henia brevis* (Silvetri, 1896); *H. vesuviana* (Newport, 1845); *Macrosternodesmus palicola* Brölemann, 1908; *Nanogona polydesmoides* (Leach, 1815); *Ophiodesmus albonanus* (Latzel, 1895); *Ophyiulus germanicus* Verhoeff, 1896); *Polydesmus susatensis* Verhoeff, 1934; *Scolopendra cingulata* Latreille, 1829; *Stosatea italica* (Latzel, 1886); *Strigamia maritima* (Leach, 1817).

Taxonomically unclear species

The taxonomic status of *Strigamia transsilvanica* and its relation to *S. crassipes* is still unclear (Spelda 2005) and needs a further revision to evaluate the distribution area. These species were not analysed here.

DISCUSSION

The results of this study confirm that the majority of species are rare due to distribution in a single country. The total distribution of a species, besides political borders, always has to be kept in mind when evaluating rarity of a species. An intensified investigation will increase the number of records within the distribution area, but would not lead to a fundamentally change of the knowledge of distribution borders.

Only 37 species have a small distribution area within Germany or adjacent countries and can be termed as real rare species or better as endemics or subendemics. While other wide spread species reach their border in parts of Germany, especially in the South. Other species are rare due to scattered distributions caused by natural reasons (inhabiting special biotopes, glacial refuge areas) or through subjective reasons (hard to find/identify, spread by human activity).

Due to the fact, that Germany is an interception point of western, southern/alpine and eastern species distributions, actually the investigations confirm the zoogeographical boundaries passing from the Harz Mountains over Regensburg south to the Inn as well as the Rhine Valley line identified by Verhoeff for myriapods (1912, 1917). Another common distribution limit is the 200 m elevation contour, which runs crosswise through Germany and separates the northern lowland fauna from the southern low mountain range fauna (Hauser & Voigtländer 2009, Reip et al. 2012). This is especially obvious in the distribution of some rare species in Eastern Germany (*Julus terrestris*, *Leptoiulus cibdellus* – Figs. 7 and 8). Entirely different faunas occur in the far south of Germany, in the Alps and the Black Forest. It is very conspicuous that nearly the half (58 %) of very rare species are restricted to Southern Germany (Fig. 2), especially to the Alps as

well as to the highlands Bavarian Forest and to the Black Forest. The latter houses also five of the seven German endemics (Table 1). Further information to these species can be seen in Reip et al. (2012). In general South Germany houses the highest diversity of diplopods (90 % of German species) and centipedes (98 % of German species), caused especially by the glacial refugia such as the adjacent Salzburg and Basel region (Spelda 1996). While most of the species were able to spread from west or east over greater parts of Germany a small number of eastern species only reached the border of Germany.

Acknowledgements

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ADDENDUM

After Wesener (2015) *Glomeris malmivaga* Verhoeff, 1912 is a synonym of *Glomeris ornata* Koch, 1847.

Wesener T. 2015: No milipede endemics north of the Alps? DNA-Barcoding reveals Glomeris malmivaga Verhoeff, 1912 as a synonym of Glomeris ornata Koch, 1847 (Diplopoda, Glomerida, Glomeridae). *Zootaxa* **3999**: 571–580.