Chilopoda in forest habitat-islands in north-west Westphalia, Germany

HEINZ-CHRISTIAN FRÜND, BIRGIT BALKENHOL & BIRGIT RUSZKOWSKI

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The occurrence of centipedes was investigated in an old, continuous Stellario-Carpinetum (oak-hornbeam) forest and eight forest isolates varying in area from 0.5 ha to 2.6 ha, in age from over 100 years to about 30 years, situated between 20 m to 2900 m from the forest. In total 17 species (13 Lithobiomorpha, 1 Scolopendromorpha, 3 Geophilomorpha) were found. Although there is a group of dominant species (*Brachygeophilus truncorum* (Bergsøe & Meinert, 1866), *Lithobius dentatus* C.L. Koch, 1844, *L. muticus* C.L. Koch, 1847, *L.forficatus* (L., 1758) occurring in nearly every site, ordination by correspondence analysis revealed three groups of communities which differ in the presence of less frequent species (*Lithobius mutabilis, L. piceus, L. agilis, L. microps* etc.): 1) in the old, continuous forest 2) in moderately isolated woodlots 3) in woodlots which are separated from the old forest by built-up areas. The analysis of scar frequencies showed that *L.forficatus* has a higher incidence of injuries in the continuous forest. For *L. muticus* the reverse is true. Catches of *L.forficatus* from pitfall traps in the continuous forest seem to decrease with increasing distance to the forest edge suggesting that this centipede is invading the forest habitat.

Keywords: centipede, Chilopoda, habitat-islands, Germany, scar frequency.

H.-C. Fründ & B. Ruszkowski, IFAB Institut für Angewandte Bodenbiologie GmbH, Ernst-Sievers-Straße 107, D-49078 Osnabrück, Germany. E-mail: hc.fruend@t-online.de.
B. Balkenhol, Staatliches Museum für Naturkunde Görlitz, PSF 425, D-02806 Görlitz, Germany.

Introduction

Man has turned many of the formerly huge and continuous woodlands in the temperate zone into a mosaic of more or less discontinuous forest patches which are surrounded by agricultural land, human settlements etc., and which are cut through by traffic lines such as roads and railways. These forest patches can be seen as habitat-islands and several authors have studied the communities of birds, ground beetles, spiders and other taxa to find out if the concepts of island biogeography are applicable to them (e.g. Levenson 1981, Luczak 1989, Bittmann et al. 1990, Haila et al. 1993, Halme & Niemelä 1993, Balkenhol 1994). Chilopoda have not yet been explicitly considered with respect to forest fragmentation.

In this paper, the centipede-catches of Balkenhol (1994) in a series of rural forest patches are analysed in comparison with an old woodland of larger area. The main questions of the study are:

- Are the centipede species occurring in the large forest different from those in the woodlots around?
- Is there an evidence for an influence of the size of a woodlot's area, it's distance to the "forest mainland", and it's age on the community of centipedes?
- Is there an evidence for centipedes immigrating into the forest and/or the woodlots?
- Is there an evidence of centipede populations beeing more stressed in the woodlots than in the continuous forest?

Study area

Centipedes were collected at five sites in an old continuous woodland and in eight isolated woodlots in the "Burgsteinfurter Land" ca. 20 km north-west of Münster (Westphalia, Germany; 52°08' N, 7°22' E). The landscape is traditional farmland with small woodlots partly connected by hedgerows surrounding the fields and meadows. Human settlement is found in individually scattered farmsteads and in a

Tab. 1. Characterisation of the study sites. B1 – B5 are different sites inside the continuous "Bagno"-forest. Ps-Gley = Pseudogley; S = sand; lS = loamy sand. Abbr. for vegetation: Stel.-Carp. = Stellario holostea-Carpinetum betuli (oak-hornbeam forest); Vio.-Querc. = Violo-Quercetorum petraeae (beech-oak forest); Bet.-Querc. = Betulo-Quercetorum roboris (birch-oak forest); Vacc.-Betu. = Vaccinio uliginosi-Betuletum pubescentis (fragment of wet birch forest). mL, mT, mF, mR & mN are average indicator values of the vegetation for light, temperature, humidity, soil reaction and soil nitrogen according to Ellenberg et al. (1991).

Plot	Area (ha)	Distance to B (m)	Soil - texture of upper horizon	soil water capacity	Vegetation	mL	mT	mF	mR	mN
B1			Ps-Gley - S	medium	Stel.-Carp.	4.4	5.3	5.5	5.7	5.2
B2			Podsol-Gley - S	low	Stel.-Carp.	5.3	5.1	5.4	4.6	4.2
B3			Ps-Gley - S	medium	Stel.-Carp.	4.3	5.3	5.3	5.8	5.7
B4			Ps-Gley - S	medium	Stel.-Carp.	4.4	5.4	5.1	5.3	5.5
B5			Ps-Gley - lS	medium	Stel.-Carp.	4.4	5.4	5.5	4.4	5.7
WL1	0.5	20	Podsol-Gley - S	low	Stel.-Carp.	5.2	5.2	5.6	5.6	5.2
WL2	1.2	80	Podsol-Gley - S	low	Stel.-Carp.	4.9	5.3	5.7	4.3	4.3
WL3	1.4	1500	Plaggenesch - lS	high	Stel.-Carp.	4.8	5.4	5.9	5.9	6.4
WL4	1.4	600	Ps.-Gley - S	medium	Stel.-Carp.	5.0	5.3	5.6	6.4	6.2
WL5	2.6	2750	Plaggenesch - lS	high	Stel.-Carp.	5.2	5.3	5.2	5.0	5.4
WL6	0.7	2000	Plaggenesch - lS	high	Vio.-Querc.	5.4	5.4	5.4	4.1	4.6
WL7	0.6	2900	Podsol-Gley - S	low-m.	Bet.-Querc.	5.9	5.3	5.8	4.0	4.1
WL8	1.5	3000	peat (worked)	high	Vacc.-Betu.	6.0	5.4	6.8	5.0	5.2

small town (19,000 inhabitants) in the center of the study area. The relief of the landscape is gently sloping (ca. 50 m above sea level). The highest elevation is 110 m above sea level in the old forest. Roads and a railway line traverse the area in a relatively dense network. A comparison of the actual situation with an old map (Anonymous 1897) shows a reduction of forests leading to the formation of woodlots WL1, WL2 and WL6, which were part of more spacious woodland in 1895 (Fig. 1). WL7, which was arable land in 1895, was afforested after 1960. WL8 developed by succesion on a worked peat bog between 1950 and 1959. The other woodlots were already identifiable as such in 1895.

The soils (Dubber 1973) are sandy with Planosols ("Pseudogley") and Gleyic Podzols ("Podsol-Gley") in the old forest and adjacent woodlots, whereas more distant woodlots have Fimic Anthrosols ("Plaggenesch") indicating that they were used as arable land in former times. Tab. 1 gives a brief characterisation of the study sites.

Methods

At every study site 5 pitfall traps with 7.5 cm diameter were positioned in a transect from the forest edge to the center of the woodlot. The distance between the traps was 5 m, so that trap one was at the forest edge and trap five 20 m inside the forest or woodlot. Only at forest site B5 all traps were 150 m apart from the forest edge. The traps were filled with a mixture of acetic acid, glycerin, water and ethanol (10:20:30:40) and exchanged every two weeks (Aug. 14 – Oct. 9 1989 and Apr. 17 – Aug. 7 1990).

To catch immigrating and emigrating individuals selectively, traps with leading boards were installed at the fringes of the woodlots WL2, WL3 and WL6 (five traps each). They consisted of three perspex plates 1 m long and 40 cm high connected in Z-form at 90° angles and with two conventional pitfall traps inside the resulting corners. The arrangement was such that one angle opened to the inside, the other to the outside of the woodlot (Fig. 2).

Soil samples were taken with a 5.7 cm diameter

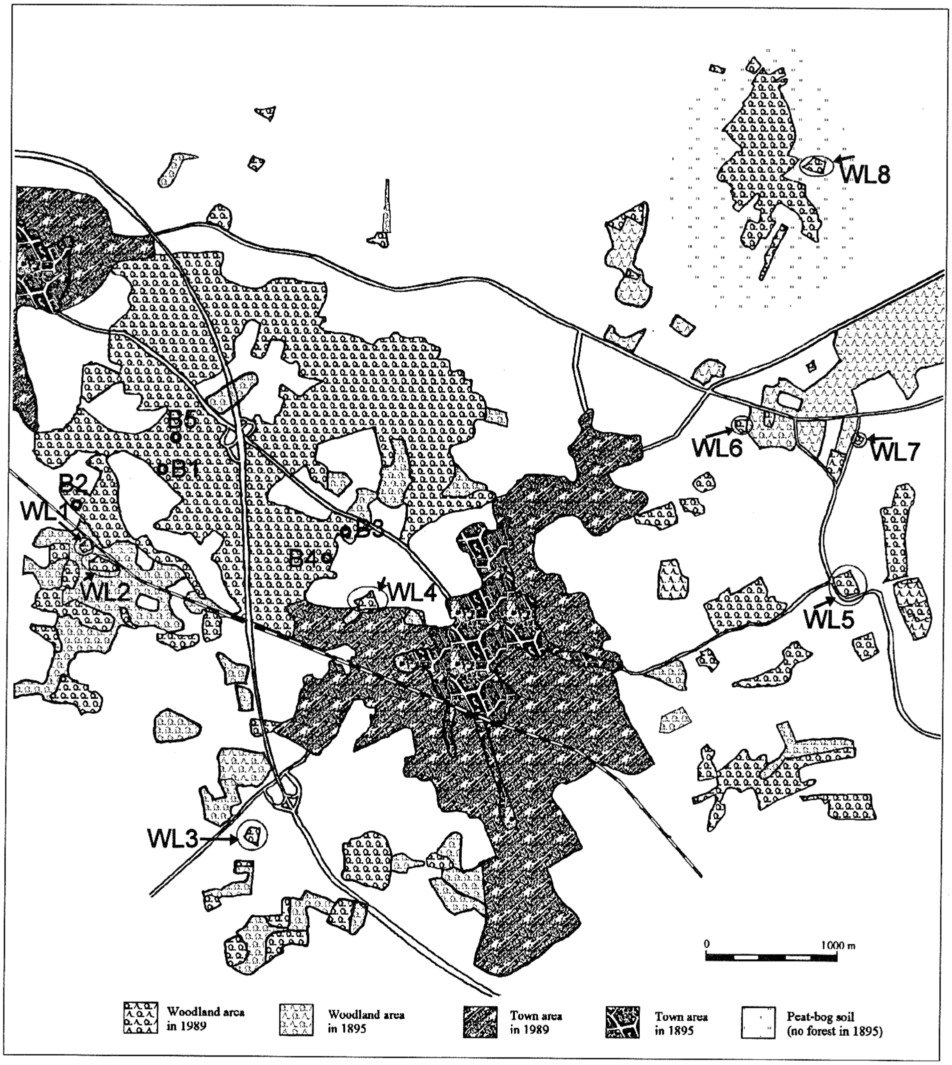

Fig. 1. Location of study sites and distribution of woodland and town area in the years 1989 und 1895. B1-5 plots in continuous, old woodland; WL1-8: Woodlots (WL7 and WL8 not being forest in 1895).

soil corer to a depth of 16 cm. They were extracted in a high gradient cylinder extractor (MacFadyen 1961) during a period of one week. Seven samples were taken at a time from each study site. The samples analysed are from Oct. 1990 – May 1991. Their total number per study site varies between 7 and 28.

All trapped animals (excluding soil samples) were analysed for cicatriced lesions (Fründ 1992) and the frequency of these scars was recorded.

Results

Species spectrum

Altogether 931 centipedes could be determined to 17 species. Fifty-one specimens are left out of the analysis because they were too young and/or too mutilated for identification. The species are listed in Tab. 2 including total catches from the different sampling methods and data on the scar frequencies. There is a great difference between soil samples and

Tab. 2. List of species found during the investigation, total catch, proportion of scarred individuals and average number of scars per individual. Scar data refer to trap-catches only.

Species	total catch from: standard traps	traps with leading boards	soil samples	% with scars	average no. of scars per indiv.
Lithobiomorpha					
Lithobius forficatus (Linné, 1758)	67	52	0	55%	1.2
Lithobius piceus L. Koch, 1862	11	5	0	63%	1.4
Lithobius dentatus C. L. Koch, 1844	148	46	0	34%	0.5
Lithobius macilentus L. Koch, 1862	3	0	0	67%	1.0
Lithobius pelidnus Haase, 1880	10	9	0	53%	0.7
Lithobius mutabilis L. Koch, 1862	25	1	1	65%	1.6
Lithobius muticus C. L. Koch, 1847	94	44	2	56%	1.1
Lithobius calcaratus C. L. Koch, 1844	11	4	0	47%	0.9
Lithobius agilis C. L. Koch, 1847	11	10	0	74%	0.7
Lithobius microps Meinert, 1868	8	5	4	46%	0.8
Lithobius curtipes C. L. Koch, 1847	1	0	0	100%	3.0
Lithobius crassipes L. Koch, 1862	29	28	5	35%	0.5
Lamyctes fulvicornis Meinert, 1868	1	0	0	100%	5.0
Lithobiomorpha juv. indet.	6	1	44		
Scolopendromorpha					
Cryptops hortensis Leach, 1815	2	0	4	0%	0.0
Geophilomorpha					
Schendyla nemorensis (C. L. Koch, 1836)	1	1	37	0%	0.0
Strigamia acuminata (Leach, 1815)	7	3	1	0%	0.0
Brachygeophilus truncorum (Bergsøe & Meinert, 1866)	14	4	222	6%	0.1
total	449	213	320		

pitfall traps. Geophilomorpha, especially *Brachygeophilus truncorum* dominated in the soil samples. Lithobiomorpha were mainly caught in the traps. The soil cores were probably too small to catch the epigeic centipedes adequately.

Species distribution

In Tab. 3 the species are arranged according to their occurrence in the study sites. The number of crosses in the table gives a rough estimate of the species' frequency taking all three sampling methods in combination. The species-sites matrix of Table 3 was subjected to a correspondence analysis (ter Braak 1987, Fründ 1995). The resulting eigenvalues are low ($\lambda_1 = 0.18$; $\lambda_2 = 0.12$) indicating that the centipede communities at the various sites are not very different from each other. Three groups of species can be distinguished. They are separated in Tab. 3 by stippled lines.

• 1. Species occurring in the continuous forest and the woodlots WL1 to WL4, but missing in the

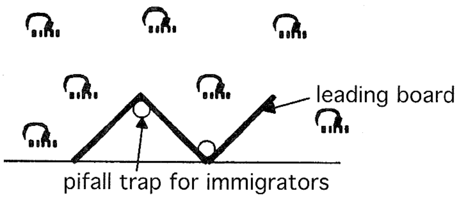

Fig. 2. Schematic sketch of traps with leading boards.

more distant and/or isolated woodlots WL5 to WL8. In this group *Lithobius mutabilis* and probably *L. curtipes* show a strong preference for the "true" forest sites. The other 5 species in this group are equally or even sligtly more frequent in the adjacent woodlots than in the forest.

• 2. Species occurring (more or less) in every study site. This group contains 6 species which are generally frequent or dominant in the whole study area.

• 3. Species missing in the forest but occurring in the woodlots. In this group of 4 species there seems to be no preference for one group of woodlots over the other.

To find out what shaped the centipede communities, the site scores obtained by the correspondence analysis (CA) were regressed against the habitat parameters given in Tab. 1. A significant correlation ($p<0.05$ in Pearson *and* Spearman correlation) turned out between the vegetational indicator value for light (mL) and the site scores in the first dimension of CA (Fig. 3). When woodlot area and distance to the "Bagno"-forest are combined into an "insularity index" (= distance/area) this index correlates strongly with the site scores of the woodlots in the first dimension of CA (Fig. 4).

Distance of trap to forest edge

When comparing the species frequencies in various distances to the forest edge a continuous decrease of *Lithobius forficatus* in the "Bagno"-forest from the forest edge to the interior could be observed (Tab. 4). In the woodlots *L. forficatus* was equally frequent in the interior and at the edge. The other species have similar distribution patterns in the forest-sites and the woodlots and there is no trend of frequency between the various distance classes. The catch numbers are not sufficient for a statistical validation of this observations. They are nevertheless communicated because of their plausibility in connection with the other results obtained.

Traps with leading boards

Traps with leading boards were installed at the

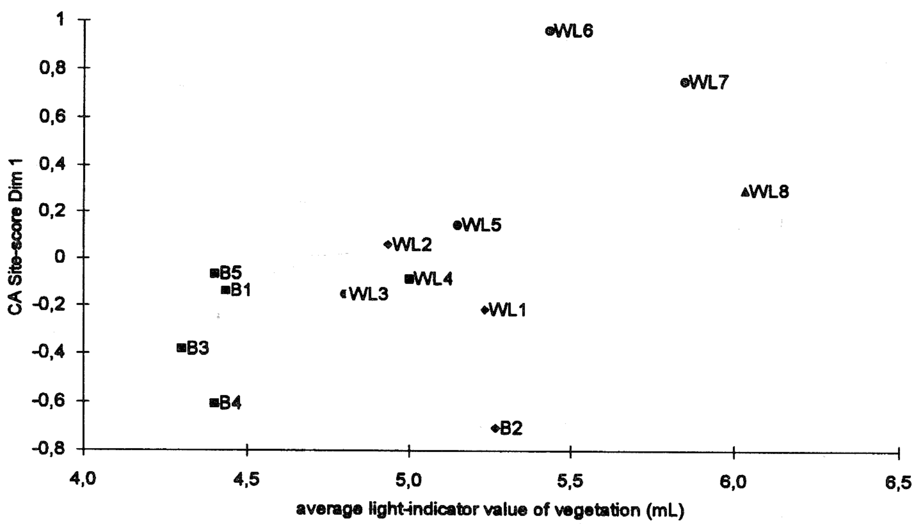

Fig. 3. Scatterplot of site scores in first dimension of correspondence analysis against vegetational indicator values for light (Spearman rank-correlation $r_S = 0.56$ $p<0.05$; Pearson-correlation $r = 0.60$ $p<0.05$). Different symbols correspond to different soil types.

Tab. 3. Occurrence of species in the 13 study sites. For the estimation of frequency-classes the different sampling methods have been combined: + = 1 specimen found, ++ = 2–4, +++ = 5–9, ++++ = 10 or more specimens found.

Species/Site	B5	B2	B4	B3	B1	WL1	WL3	WL4	WL2	WL5	WL8	WL7	WL6
Lith. curtipes			+										
Lith. mutabilis	++	++	+++	+++	+++		+	+			+		+
Crypt. hortensis		++				+							
Lith. piceus		++	++	++	++	+	++	++	++				
Lith. pelidnus		+		++		+	++	++	++				
Stri. acuminata			+			++	+		++				
Lith. macilentus			+			+	+						
Lith. crassipes		+++	+	+++	+++	++	+++		+++	++++	+		
Sch. nemorensis		++	++	++	++	++	+++				+++	+++	
Bra. truncorum	++++	+++	++	++++	++++	+++	++++	+	++++	++++	++	++++	+++
Lith. dentatus	+++	+	+++	++++	++++	++++	++++	+++	+++	++++		++++	++++
Lith. muticus		++	++	+++	++++	+++	+++	+	++	+++	++++	++++	++++
Lith. forficatus	++	++	++	++	+++	++	++	+	++	+++	++++	++++	++++
Lith. agilis						++	+		++			++	++
Lith. microps							++	++			++	++	++
Lith. calcaratus					+				++	+		+++	++
Lam. fulvicornis													+
No. of. species	4	10	11	9	9	12	13	8	10	6	7	8	9

forest fringes of the woodlots WL2, WL3, and WL6. There was no significant difference between the inner and outer trap - either for particular species or for the centipedes in total. The efficiency of catching is higher with leading boards. This effect is most pronounced in *Lithobius forficatus* and *L. crassipes,* where the frequencies are more than double, but less so in *L. dentatus* and *L. muticus*.

Scar frequencies

The general scar frequency differs considerably from species to species (Tab. 2). *Lithobius dentatus* and *L. crassipes* have relatively few scars while more than every second *Lithobius muticus* and *Lithobius forficatus* had some kind of old injury. There are significant differences in scar frequencies between the "Bagno"-forest and the isolated woodlots (Tab. 5).

Discussion

The woodlots as well as the continuous forest are essentially populated by a forest community of centipedes. With increasing island character and distance from the "mainland forest" eurytopic species and those from open habitats add to this species assemblage, but - with the exception of *L. forficatus* - do not reach dominant positions. The available evidence is not sufficient to prove an island effect on the centipedes in the woodlots. The correlation with light intensity (Fig. 3) suggests that the climatic situation inside the woodlots plays a role in determining which species can settle. On the other hand, the division between the woodlots with and without species of the "Bagno"-forest also corresponds to the separating line that the town area draws between the woodlots in their connection with the old continuous forest. Therefore it is reasonable to suppose that dispersal and colonization processes may have an influence. Centipedes, especially Lithobiomorpha, most probably colonize new habitats as walking mature individuals. This conclusion can be drawn from the generally high preponderance of adults in pitfall-traps compared to quadrat-sampling (Dunger 1966). To our knowledge the dispersal of centipedes has not yet been studied in detail.

The communities of carabid beetles at the study sites show a similar distinction between the woodlots on either side of the town area, but the difference between the "Bagno" forest and the woodlots WL3 and WL4 is less clear than with the Chilopoda

Tab. 4. Total number of *Lithobius forficatus* caught in standard traps with increasing distance from the edge to the forest interior in the continuous forest ("Bagno") and the woodlots.

Distance to forest edge	0 m	5 m	10 m	15 m	20 m
"Bagno"-sites (B1-B4, 20 traps at each distance)	6	4	3	1	0
Woodlots (WL1-WL8, 40 traps at each distance)	14	8	3	10	12

(Balkenhol 1994).

Judging from the scar frequencies no general adversity of the forest patches for centipedes can be concluded. *L.dentatus* seems to do equally well in the old forest and the isolated woodlots. This centipede seems to be the most frequent *Lithobius* in deciduous woodland in the geographical region studied (Vossel 1994, Löser 1982, Fründ unpubl.) Its scar frequency in this area is significantly lower than in beech forests in southern Germany, where the species occurs only sporadically (Fründ 1992). For *L. forficatus* the "Bagno" forest seems to be less favorable than the woodland patches. Its higher scar frequency in the old forest goes well with the observed decrease of abundance from the fringe to the forest-interior. But also in the woodlots the scar frequency of *L. forficatus* is higher than in samples from urban habitats and from a pine forest (< 30%, Fründ 1992) suggesting that oak forest is not its optimal habitat. In combination with the decrease of specimens caught along the trap transect into the forest, it can be speculated that *L. forficatus* has a tendency of invading the forest habitat from the open land. From the literature *L. forficatus* is already known as a highly mobile species which frequently enters buildings and is among the first ones to appear in reclaimed land (Barber & Keay 1988, Dunger & Voigtländer 1990, Fründ 1989).

L. muticus has a lower scar frequency in the old forest than in the woodlots. This might support the opinion that it is basically a forest species (especially of oak forests), taking other situations as a "second choice". *L. muticus* is also known to be more restricted to the litter habitat than the other two species (Barber & Keay 1988). Small woodlots are intensely frequented by mammals and birds. Therefore the litter habitat there may be disturbed more often than it is in the continuous forest.

The record of *L. mutabilis* in the "Bagno"-forest expands the north-western border of its known

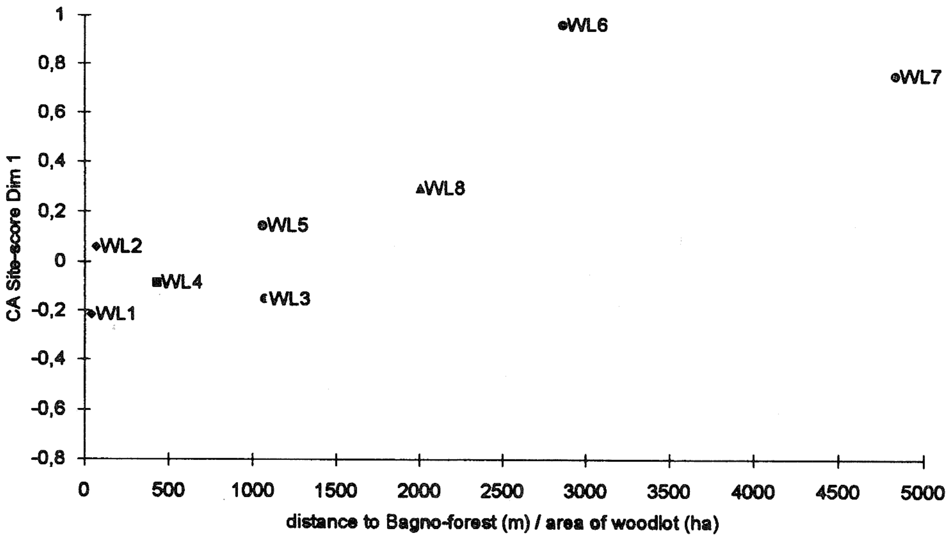

Fig. 4. Scatterplot of site scores in first dimension of correspondence analyse against "insularity index" (Spearman rank-correlation rS = 0.81, p<0.05; Pearson-correlation r = 0.85, p<0.05). Different symbols correspond to different soil types.

Tab. 5. Frequency of scarred centipedes in populations from the continuous Bagno-forest and from ± isolated woodlots

	% of indiv. with scars		
	Bagno-forest	woodlots	signif. of difference
L. forficatus	69	47	$\aleph^2 = 4.53$; $p \leq .03$
L. muticus	39	63	$\aleph^2 = 4.18$; $p \leq .038$
L. dentatus	26	32	n.s.

geographical distribution. The species is interesting because it shows a significant preference for the old, continuous forest but is also found as singletons in the small, distant woodlot WL6 and even in the successional birch forest of WL8. *L. mutabilis* was also found in woodland relics in Warsaw, Poland (Wytwer 1995) and in a meadow 470 m above sea level in the Solling, Germany (Albert 1982). In Slovenia it is frequently found in meadows (I. Kos, pers. comm.).

It can be concluded that the forest habitat-islands differ from the continuous woodland in the occurrence of species as well as in the adversity they impose on the more abundant and ubiquituous species of Lithobiomorpha.

Observing the occurrence of scars in Lithobiomorpha offers valuable information when interpreting the status of a population.

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