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Millipedes and centipedes in wetland alder stands in north-eastern Poland

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Abstract

Using soil sampling and subsequent heat extraction of animals, four alder stands in the wetlands of the Biebrza, Narew and Białowieża national parks, north-eastern Poland, were surveyed for millipedes and centipedes. Among 12 millipede species revealed, *Xestoiulus laeticollis*, *Polydesmus complanatus* and *Craspedosoma rawlinsii* occurred and predominated in all alder woods. The centipede fauna was very poor, altogether represented by four species, only *Lithobius curtipes* being shared by all sites. The myriapod communities from the swampy alder woods (Ribeso nigri-Alnetum) at Biebrza and in the Białowieża Primeval Forest were mainly under the influence of fertility soil parameters (available and total phosphorus contents) while the assemblage from an alder swamp at Narew was largely affected by soil humidity. Apparently, the community from an ash-alder alluvial wood (Fraxino-Alnetum) sampled in the Białowieża Primeval Forest mostly depended on soil pH. Comparing all available information, the structure of myriapod assemblages seems to be quite similar even over distant regions in Central Europe.

Keywords: millipedes, centipedes, alder woods, Poland

1. Introduction

Alder woods represent one of the characteristic habitats of river flood-plains both in lowlands and uplands across much of Europe. The high water-table determines specific soil and vegetation conditions, consequently, also particular soil invertebrate communities (Adis & Junk 2002). Sufficient amounts of easy-to-decompose leaf litter ensure the development of assemblages of soil saprophagous invertebrates, as well as predatory groups, including millipedes and centipedes.

Even though some faunistic information concerning on millipede and centipede assemblages of such habitats has long been available, particularly from the Białowieża Primeval Forest (Tarasevich 1992, Wytwer 1997, 1999a, b, 2000, Wytwer & Tracz 2003), detailed knowledge of the patterns of myriapod community structure in alder woods and the main factors they are affected by is still fragmentary and scarce. The objective of the present paper is to demonstrate variation in myriapod communities of four alder forests in north-eastern Poland within the context of selected soil properties of the study stands.

2. Study sites

The alder woods of Central Europe belong to two phytosociologically different classes: *Alnetea glutinosae* Br-Bl. & R. Tx. 1943 and *Quercetea robori-petrae* Br-Bl. & R. Tx. 1943. Their differentiation depends on the way they are fed with water, i.e. stagnant or flowing water (Chytrý et al. 2001, Matuszkiewicz J. M. 2001). Among the numerous phytosociological associations with alder occurring across the Central European Lowland, the following two are the most common in Poland (Matuszkiewicz W. 2001):

Alder carr (Ribeso nigri-Alnetum Sol. Górn. (1975) 1987, earlier considered as Carici elongatae-Alnetum Koch 1926 (in CORINE 44.91 alder swamp woods), representing the alliance of Alnion glutinosae Malcuit 1929 from the first of the above phytosociological classes.

Ash-alder alluvial forest (Fraxino-Alnetum W. Mat. 1952 (= Circaeo-Alnetum Oberd. 1953 (in CORINE 44.3 medio-European stream ash-alder woods), representing the alliance Alno-Ulmion Br-Bl. & R. Tx. 1943 from the second of the above-mentioned classes.

Millipede and centipede assemblages were investigated in four alder stands selected in the large wetland areas of northeastern Poland. Three of them represent alder carrs:

Biebrza National Park, Lower Basin, Barwik, alder swamp wood Ribeso-nigri Alnetum, 53°22'35"N, 22°33'34"E.

Narew National Park, Kurowo, alder swamp wood Ribeso-nigri Alnetum, 53°06'58"N, 22°47'46"E.

Białowieża Primeval Forest I, Hajnówka District, Topiło, forest sections 514D/539B, alder swamp wood Ribeso-nigri Alnetum, 52°39'49"N, 23°37'01"E.

The fourth stand represents ash-alder alluvial forests:

Białowieża Primeval Forest II, Hajnówka District, Topiło, forest section 600C, medio-European stream ash-alder wood Fraxino-Alnetum, 52°38'08"N, 23°37'54"E.

3. Materials and methods

Five soil samples, each 1/16 m^2 in area and about 10 cm in depth, were taken in each stand in October 2003 and transported into the laboratory. The animals were obtained by 10 days heat extraction in the laboratories of the Institute of Soil Biology BC AS CR using the modified Kempson apparatus (Kempson et al. 1963).

Simultaneously, soil samples were taken for gravimetric estimation of actual soil humidity (H) and selected soil chemical parameters (Tab. 1): Soil pH was measured in water solution (pH1) and in solution of potassium chloride (pH2) (Kubíková 1970). Soil fertility parameters, such as total content of phosphorus (Pt) was determined according to Sommers & Nelson (1972), available phosphorus (Pv+k) and water-soluble phosphorus (Pv) were measured according to Macháček (1986) and Murphy & Riley (1962) in modification of Watanabe & Olsen (1965). Percentage content of oxidable carbon (C) was determined according to Králová et al. (1991), and sodium (Na), potassium (K) and calcium (Ca) contents were measured according to Kubíková (1970) and Nedoma (1990).

Tab. 1 Actual soil humidity (H) and selected soil chemical parameters of the study alder woods of the northeastern Poland. pH1 (pH H_2O) – pH of soil measured in water solution, pH2 (pH KCl) – soil pH measured in solution of potassium chloride, Pt – phosphorus in total, Pv+k – phosphorus available, Pv – phosphorus water soluble, C – oxidable carbon.

	Biebrza NP	Narew NP	Białowieża Forest I	Białowieża Forest II
H (%)	67.2	75.1	69.8	67.0
pH1 (pH H_2O)	5.14	5.70	5.64	6.40
pH2 (pH KCl)	4.50	5.20	5.3	5.85
Pt (mg kg^{-1})	1271	1104	1607	1434
Pv+k (mg kg^{-1})	44	47	49	55
Pv (mg kg^{-1})	38	35	33	33
C (%)	23.30	15.92	16.58	18.38
Na (mg kg^{-1})	68	72	56	8
K (mg kg^{-1})	116	90	146	72
Ca (mg kg^{-1})	4960	3724	3260	4556

Multivariate analyses were implemented to study the ecological date on myriapod species and on the soil parameters. The length of ordination axes in Detrended Correspondence Analyses (DCA) with detrending by segments, as well as Hill's scaling which measures the beta-diversity along individual independent gradients (Hill & Gauch 1980, ter Braak & Verdonschot 1995, Jongman et al. 1995) were employed for designing which type of constrained analysis (linear or unimodal) is better to be used for the study of species variability patterns (Lepš & Šmilauer 2003). Therefore, Redundancy Analyses (RDA) was employed as the most proper constrained ordination to study variation in the myriapod assemblages across the soil parameters. RDA was made with species data log transformed, with scaling focused on inter-samples correlation and with standardisation by species centered. Analyses of zoocoenological data were made using the PAST (http://folk.uio.no/ohammer/past) and CANOCO 4.5 (ter Braak & Šmilauer 2002) programs.

4. Results

Species richness and abundance

Twelve millipede and only four centipede species were found on all four study sites. The site representing the ash-alder alluvial habitat in the Białowieża Primeval Forest (Białowieża Forest II) was characterised by a myriapod community with the highest species richness, as well as the highest abundance (Tab. 2). The number of millipede species found on this site was 3 times higher than in the alder swamp wood of the Narew NP. The population density of millipedes was also 3 times as high as estimated on two other study sites (Narew NP and Białowieża Forest I). This ash-alder alluvial stand at Białowieża was also the richest in centipedes, both in species number and abundance. Among three sampled alder carrs (swamp woods), the site in the Biebrza NP was the richest in millipede species (Tab. 2). Two species, *Mastigona vihorlatica* and *Megaphyllum sjaelandicum*, were found only there.

Based on our own observations, we used the species name *M. vihorlatica* although the taxonomical status of *M. vihorlatica* and *M. bosniense* is not yet clear (compare Hauser 2004).

Tab. 2 Millipede and centipede assemblages of the study alder woods of the north-eastern Poland. List of species with abbreviations used in DCA and RDA analyses; densities (ind. m^{-2}) and numbers of species.

	abbrev. of spp. names	Biebrza NP	Narew NP	Białowieża Forest I	Białowieża Forest II
Diplopoda					
Blaniulinae gen. sp. juv.	*Blan*	–	–	3.2	–
Craspedosoma rawlinsii Leach, 1814	*Craw*	9.6	22.4	19.2	19.2
Glomeris tetrasticha Brandt, 1833	*Gtet*	9.6	–	6.4	60.8
Mastigona vihorlatica (Attems, 1899)	*Mvih*	3.3	–	–	–
Mastigophorophyllon saxonicum Verhoeff, 1916	*Msax*	–	–	–	3.2
Megaphyllum projectum Verhoeff, 1894	*Mproj*	–	–	–	6.4
Megaphyllum sjaelandicum (Meinert, 1868)	*Msjae*	12.8	–	–	–
Xestoiulus laeticollis (Porat, 1889)	*Xlaet*	19.2	147.2	54.4	124.8
Polydesmus complanatus (Linnaeus, 1761)	*Pcom*	22.4	57.6	16.0	60.8
Polyzonium germanicum Brandt, 1837	*Pger*	19.2	–	96	9.6
Rossiulus vilnensis (Jawlowski, 1925)	*Rvil*	–	–	–	22.4
Strongylosoma stigmatosum (Eichwald, 1830)	*Sstig*	–	–	–	19.2
Total density (ind. m^{-2})		96.0	227.2	108.8	326.4
± SE		26.3	28,8	15.5	33.4
Number of species		7	3	6	9
Chilopoda					
Lithobius curtipes C. L. Koch, 1847	*Lcur*	12.8	22.4	3.2	28.8
Lithobius mutabilis L. Koch, 1862	*Lmut*	–	–	3.2	6.4
Lithobius pelidnus Haase, 1880	*Lpel*	–	–	–	3.2
Lithobius sp. juv.	*Lsp*	6.4	–	–	–
Geophilus proximus C. L. Koch, 1847	*Gprox*	–	3.2	–	3.2
Total density (ind. m^{-2})		19.2	25.6	6.4	41.6
± SE		7.8	11.9	3.9	9.6
Number of species		2	2	2	4

Dominance structure

Among millipedes, three species, *Xestoiulus laeticollis*, *Polydesmus complanatus* and *Craspedosoma rawlinsii*, were recorded in all study sites, also predominating there (Fig. 1). Among centipedes, only one species, *Lithobius curtipes*, was discovered in all study sites, everywhere as a dominant.

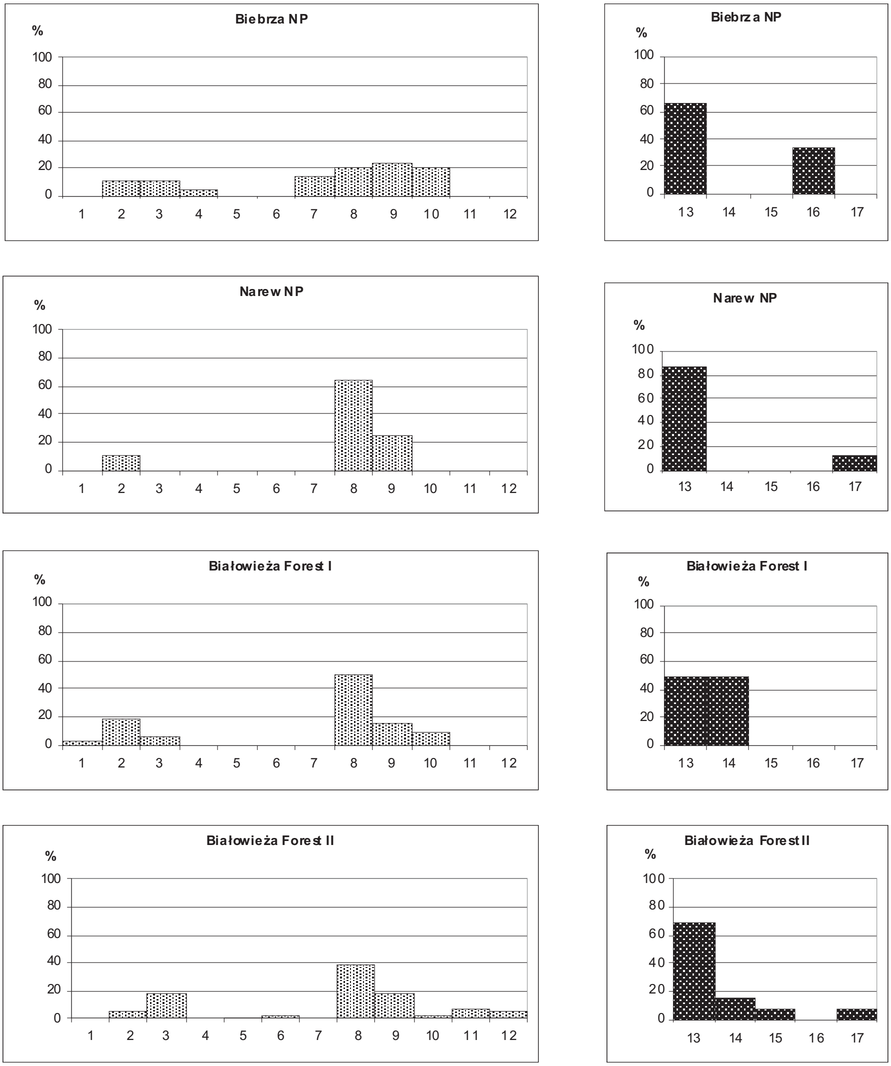

Fig. 1 Dominance structure (%) of myriapod communities of alder forest in north-eastern Poland. Diplopoda: 1: Blaniulinae gen. sp. juv.; 2: *Craspedosoma rawlinsii*; 3: *Glomeris tetrasticha*; 4: *Mastigona vihorlatica*; 5: *Mastigophorophyllon saxonicum*; 6: *Megaphyllum projectum*; 7: *Megaphyllum sjaelandicum*; 8: *Xestoiulus laeticollis*; 9: *Polydesmus complanatus*; 10: *Polyzonium germanicum*; 11: *Rossiulus vilnensis*; 12: *Strongylosoma stigmatosum*. Chilopoda: 13: *Lithobius curtipes*; 14: *Lithobius mutabilis*; 15: *Lithobius pelidnus*; 16: *Lithobius* sp. juv.; 17: *Geophilus proximus*.

Diversity

The values of Shannon diversity index for both myriapod groups show similar trends, with relatively high values found in the communities of the ash-alder alluvial wood in the Białowieża Primeval Forest (Białowieża Forest II) and the lowest values in the assemblages from the alder swamp wood in the Narew NP (Fig. 2). The opposite situation concerns the Pielou evenness index. The lowest values were recorded in the communities of both myriapod groups in the ash-alder alluvial wood in the Białowieża Primeval Forest (Białowieża Forest II).

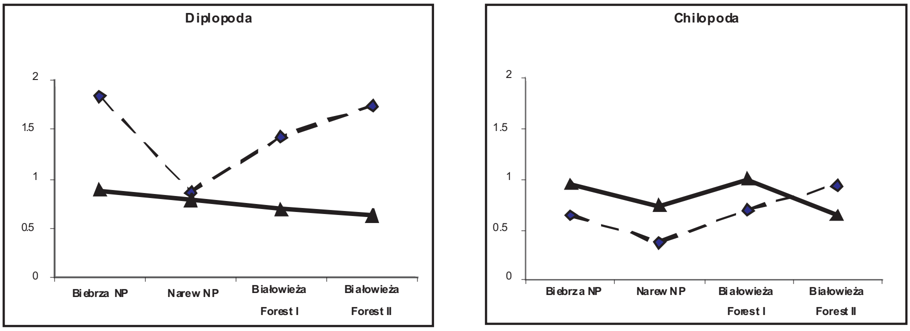

Fig. 2 Diversity indices of the millipede and centipede communities in the study alder stands: Shannon diversity index (– – ♦ – –) and Pielou evenness index (—▲—).

Variation range

Since unconstrained ordination can help for estimating the range of species data variation, detrended correspondence analysis (DCA) was used (Hill & Gauch 1980). According to this analysis, the samples from the study alder woods represent a relatively uniform group (Fig. 3): the length of the gradient (= 2.868) measuring the beta-diversity in the community appeared to be rather short, with the value below 3 (Lepš & Šmilauer 2003).

The most heterogeneous group of samples, i.e., the most distant from one another in the DCA diagram, comes from the Biebrza NP. Relatively heterogeneous were also the samples taken from the swampy alder wood in the Białowieża Primeval Forest. The most homogeneous groups (with sample scores laying most closely one another in the diagram) were composed by samples from the ash-alder alluvial site in the Białowieża Primeval Forest (Białowieża Forest II) and, especially, from the Narew NP (Fig. 3).

The most typical species of the alder stands were the above dominant millipedes, i.e. *Xestoiulus laeticollis*, *Polydesmus complanatus* and *Craspedosoma rawlinsii*, as well as the dominating centipede species *Lithobius curtipes*. All these species were grouped closely together in the DCA diagram within the cluster of soil samples. The other myriapods less common in this type of wood shifted beyond the cluster of all soil samples (Fig. 3).

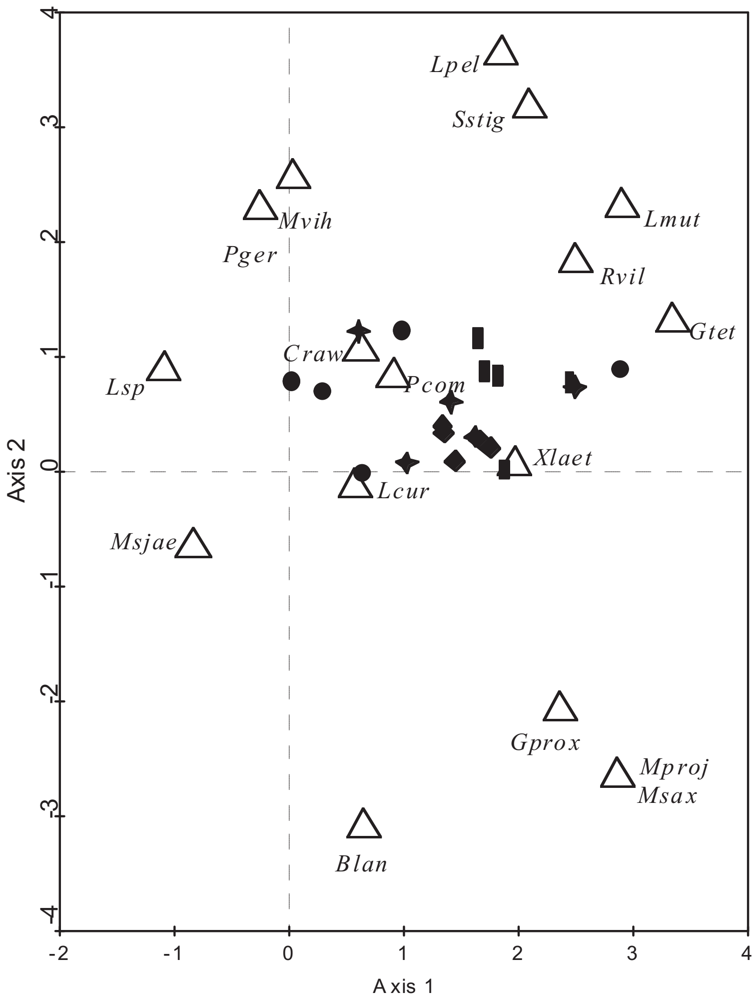

Fig. 3 DCA diagram for the myriapod communities of alder forests from the study sites; empty trangles (?) – myriapod species (abbreviations see Tab. 2), filled circles (●) – samples from swampy alder wood in Biebrza NP, filled diamonds (◆) – swampy alder wood in Narew NP, filled stars (✦) – swampy alder wood – Białowieża Forest I, filled boxes (■) – ash-alder alluvial wood – Białowieża Forest II.

Influence of soil chemical properties

Redundancy analysis (RDA) was used to study changes in myriapod assemblages across the measured soil characteristics (Tab. 1). The RDA results showed that the measured soil parameters could explain almost half of the variation (42.6 %) in the study myriapod communities. According to the RDA diagram (Fig. 4), the communities from the swampy alder woods in the Biebrza NP and the Białowieża Primeval Forest (Białowieża Forest I) were under the main effect of fertility soil parameters while the myriapod community from the swampy alder wood in the Narew NP was largely affected by soil humidity. The myriapod community from the ash-alder alluvial wood in the Białowieża Primeval Forest (Białowieża Forest II) seems to have mostly depended on pH of the soil.

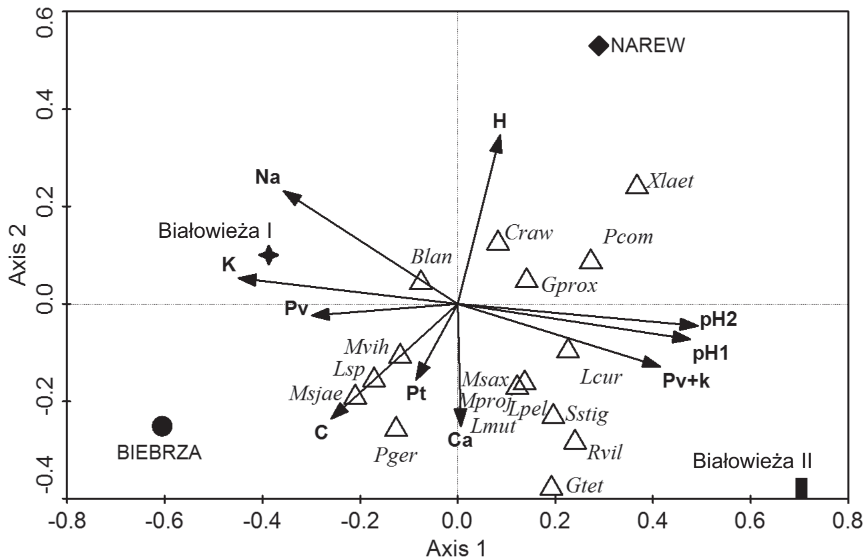

Fig. 4 RDA diagram for the myriapod communities of alder forests from the study sites; myriapod species abbreviations – see Tab. 2, arrows – environmental variables (see chapter Materials and methods), sample symbols – see Fig. 3.

4. Discussion

The list of millipede species based on soil sampling contains 12 taxa, which seems to be quite incomplete for the given type of habitat in north-eastern Poland. Altogether, 13 species have been found in the ash-alder forest in the strict reserve as in section 600 C (here studied) of the Białowieża Primeval Forest alone (Wytwer 1997). However, millipede material obtained only once with such a limited soil sampling protocol applied could naturally be expected to be somewhat poorer than that collected throughout the season by pitfall trapping. Therefore, the lack of *Ommatoiulus sabulosus*, *Proteroiulus fuscus* and *Leptoiulus proximus* or *Nemasoma varicorne* found earlier in the Białowieża Primeval Forest (Wytwer 1997, Wytwer & Tracz 2003) showed that these species were not too typical of wet habitats and occurred in alder forests but accidentally. *Megaphyllum sjaelandicum* was not revealed in the earlier studies in the same stand (Białowieża Primeval Forest II). Furthermore, the millipede densities obtained in this study (from about 100 to above 300 ind. m^{-2}) are very high, about 10 times higher compared with the previous data from the same type of habitat where material had only been hand-sorted (Lokšina 1964, Wytwer 1997). The dominance structure of the most abundant species *Xestoiulus laeticollis*, *Craspedosoma rawlinsii* and *Polydesmus complanatus* seemed to be quite typical of alder woods of the eastern regions of Poland and of the western part Byelorussia (Lokšina 1964, Tarasevich 1992, Wytwer 1997, Ožanová 2000).

In other parts of Europe, model structures of such millipede assemblages seem to be quite similar. Thus, Gulička (1960) recorded in the same type of habitat in Slovakia three dominant millipede species as well, either the same or congeners, or from close genera: *Craspedosoma rawlinsii* (= *simile* Verhoeff, 1891), *Polydesmus denticulatus* C. L. Koch, 1847 instead of *P. complanatus*, and *Leptoiulus cibdellus* (Chamberlin, 1921) [= *L. minutus* (Porat, 1889)] instead of *Xestoiulus laeticollis*. Both latter are tiny and closely related millipedes. In addition, he found still another small juliform, *Proteroiulus fuscus* (Am Stein, 1857), as the fourth highly abundant species, similarly to the observations by Ožanová (2000) who reported it in a wet habitat with alder in the Poleski NP. However, the presence of this species can also be related to decaying wood other than alder, for instance pine wood which this species can inhabit in great abundance (Tracz 1984).

Only four centipede species found in the study alder woods certainly fail to exhaust the list of species occurring in this type of habitat where at least 6–7 species must occur (Wytwer 1999a). However, most of them belong to the genus *Lithobius* whose members are mainly epigeic and able to hide among tree roots rather than in hollows between trees in the sampled area. Still the results of earlier studies (Wytwer 1999a) were confirmed as regards the values of centipede abundance in the alder woods of the Białowieża Primeval Forest, as well as the dominance of the most abundant *Lithobius curtipes* and *Geophilus proximus*. In this type of swampy alder habitat in Slovakia, depending on the season of sampling, Gulička (1960) recorded 2–4 centipede species. Among them, only *L. mutabilis* was also found in alder woods in Slovakia; instead of *G. proximus* extracted from our samples he found *Pachymerium ferrugineum* (C. L. Koch, 1835) to be the most abundant centipede while *L. aeruginosus* L. Koch, 1862, a consubgener, was revealed instead of *L. curtipes*.

The range of variation in myriapod communities in the study sites appears to be quite modest. This results from low species richness values seen in this type of habitat, as neither alpha- nor beta-diversity could change too much. The most heterogeneous group of samples was found in the alder swamp wood in the Biebrza NP, where the myriapod community was under the greatest influence of fertility soil parameters. These are probably the main limiting factor there, because the alder swamp wood was situated between fens and transition mires which belong to very poor habitats. The communities from this site were relatively rich and they realised well their potential diversity (high values of the evenness index) in the hard environmental conditions. The most homogeneous samples were collected from the ash-alder alluvial wood in the Białowieża Primeval Forest. The myriapod community was the richest there but the species evenness was not high. The acidity level was the most important parameter to account for its variation. In turn, humidity was probably the most profound limiting factor for myriapods from the alder swamp wood in the Narew NP, this probably accounting for the poorest myriapod community revealed there. Simultaneously, the community showed relatively high evenness values under very hard environmental conditions. After all, it is humidity that has long been known to be the basic limiting factor for all myriapods (Hopkin & Read 1992, Branquart et al. 1995). Different parameters of water regimes in alder carrs (usually wet over the whole year) and ash-alder alluvial forests (with short spring floods) should be also mentioned, although detail parameters for the studied sites were not available.

Finally, the development and persistence of millipede as well as centipede assemblages in flood alder forests can be stated to mainly depend on physical, autecological factors in geographically closely lying regions. However, structural models of such assemblages seem to be quite similar in more distant regions in Central Europe. Nevertheless, further detailed studies in this field are needed.

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