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Distribution pattern of woodlice (Isopoda) and millipedes (Diplopoda) in four primeval forests of the Western Carpathians (Central Slovakia)

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Abstract

We collected 1605 isopod individuals (eight species) and 671 diplopod individuals (17 species) in four primeval forests of the Western Carpathians, Central Slovakia, by leaf litter extraction. The forests are of different temperate deciduous forest types varying in tree species, aspect, elevation and soil characteristics. The oak forests, established on southwest oriented slopes at an elevation of 280–600 m, were characterized by *Hyloniscus riparius*, *Porcellium conspersum*, *Enantiulus nanus* and *Ophioiulus pilosus*. The beech forests, established on northeast oriented slopes at an elevation of 700–1100 m, were characterised by *Ligidium hypnorum*, *Trachysphaera costata* and *Polyzonium germanicum*. A remarkable increase of the total number of species and individuals occurred in both forest types adjacent to coarse woody debris (CWD). Woodlice density close to CWD was between 200 and 630 individuals m^{-2} (35–130 individuals m^{-2} distant from CWD); millipede density close to CWD ranged from 60 to 230 individuals m^{-2} (15–75 individuals m^{-2} distant from CWD). Species richness of both taxa close to CWD varied from 13 to 16 species m^{-2} (7–12 species m^{-2} distant from CWD). Thus, CWD has a significant influence on saprophages. However, structural components such as CWD and the amount of leaf litter did not significantly alter species assemblages. Species at sites distant from CWD were a subset of species at sites close to CWD. According to a canonical correspondence analysis (CCA), 'forest type' and 'elevation within a slope', as well as chemistry of the upper soil layer, i.e. 'acidification' and 'nutrition', strongly influenced species assemblages.

Keywords: Primeval forests; Coarse woody debris (CWD); Leaf litter; Soil quality; Isopoda; Diplopoda; Central Europe

1. Introduction

It has long been recognized that commercial forests do more than provide timber. They support various game species and represent habitats for many arthropod species not present in any other ecosystem (Kappes and Topp, 2004). Ecologically oriented forestry, which places emphasis on natural patterns and processes in forest ecosystems, has been made possible through advances in the fields of forest biology and technology (Seymour and Hunter, 1999). However, ecologically oriented forestry is often at odds with economic constrains foresters are exposed to. For example, small-diameter deadwood which is of no economic value for industrial use can often be sold as firewood instead of being left to decay. Therefore, many commercial forests, although managed under aspects of sustainability, are characterized by a low amount of deadwood, usually ranging from 1 to 3 m^3 ha^{-1} (Ammer, 1991).

We selected primeval forests to study the impact of coarse woody debris (CWD) on the distribution pattern of woodlice and millipedes living on the forest floor. One prominent character of primeval forests is the large amount of deadwood accumulated especially during late stages of succession. Korpel (1995), who described the dynamics of forest mosaics for many primeval forests of the Western Carpathians, calculated the amount of deadwood to be between 18 and 47 m^3 ha^{-1} in oak forests and between 220 and 347 m^3 ha^{-1} in beech-fir forests.

Woodlice and millipedes were selected for our analysis because they can have key positions in decomposition and nutrient cycling of forest ecosystems (Lebrun, 1987; Anderson, 1988). In nutrient poor soils, the amount of

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nutrients released by saprophages can be substantial for ecosystem functioning (Kautz and Topp, 1998).

Our hypothesis is that coarse woody debris (CWD) is an important component on the forest floor. It not only offers an adequate habitat for xylophagous species of different animal groups (McMinn and Crossley, 1996), but also supplies a suitable habitat for saprophagous arthropods of the forest floor.

We assume that the beneficial effect of CWD is discernible not only beneath logs but also in their vicinity. We hypothesize, firstly, that species richness and species density will be increased on the forest floor close to CWD. Secondly, species assemblages will differ between sites close to CWD and sites distant from CWD. Thirdly, both effects will be independent of the forest type.

2. Materials and methods

2.1. Description of study sites

The primeval forests selected for our study are situated in Central Slovakia (Table 1). They are natural reserves within extensively managed forests in the Kremnické vrchy (forests: Boky and Badin) and the Pol'ana mountain range (forests: Rohy and Pol'ana). In both mountain ranges one primeval forest is characterized by a mild climate because of its relatively low elevation and slopes facing mainly S or SW, whereas the other one is characterized by harsher climate because of a higher elevation and slope aspect with less intense radiation (Table 1). The distances between primeval forests are between 10 and 30 km. The dominant tree species in both southerly exposed primeval forests are oaks (*Quercus polycarpa*, *Quercus cerris*), whereas beech (*Fagus sylvatica*) and fir (*Abies alba)* predominate in the other two forests. The standing crop ($m^3\ ha^{-1}$) in both oak forests did not differ significantly. It was less than 50% of the amount in both mixed beech-fir forests. Similarly, the amount of coarse woody debris (CWD, logs with a diameter >20 cm) in the oak forests was significantly lower than in both beech-fir forests. Sunlight penetrated locally through the canopy to the forest floor in both oak forests. A similar situation was found in the Pol'ana primeval forest. Here, windthrows resulted in a reduction of crown closure well below 1.0 in the area of our study plots (Table 1). In contrast, the Badin primeval forest was characterized by the very dense canopy. Soil types in oak and the beech-fir primeval forests were different. All forests were well preserved and did not show any symptoms of damage due to air pollution.

2.2. Field sampling

Our investigations were carried out from May to July 2003. The experimental design involved adequate replication and randomization (Hurlbert, 1984; Johnson, 1999). In order to test the influence of CWD we distinguished between sample sites close to coarse woody debris (c-CWD: mean distance from CWD<10 cm) and those distant from coarse woody debris (d-CWD: mean distance from CWD>200 cm). CWD regarded in this study were moderately to strongly decayed logs, ranging from $Z^0$2 to $Z^0$4 (Albrecht, 1991), with a diameter of at least 20 cm and a minimum length of 200 cm. The decayed logs, including the adjacent habitats, were regarded as distinct habitats of the forest floor. In each forest we sampled transects (Table 1) situated on the upper slope and on the lower slope.

We sampled the litter layer (L and O horizon) at c-CWD and d-CWD sites. Each leaf litter sample covered an area of 300 cm^2. In total, we sampled 64 plots per forest (eight replicates × two sites × two transects × two sampling dates). Extraction of soil arthropods from leaf litter was carried out using Tullgren funnels, with simultaneous extraction of 32 litter samples. Everywhere where the leaf litter had been collected, we sampled an adequate amount of the upper soil for chemical analyses during our first collection series. To minimize seasonal effects we began our studies in the forests characterized by S and SW slope direction, and continued in the forests with a slope directed towards the N

Table 1
Main features of the primeval forests (Boky, Rohy, Pol'ana, Badin) of the Western Carpathians

	Rohy	Boky	Pol'ana	Badin
Mountain range	Pol'ana	Kremnické vrchy	Pol'ana	Kremnické vrchy
Nature reserve since	1986	1964	1981	1913
Size (ha)	25	176	40	31
Transect elevation (m) above s.l.	400, 550	400, 550	980, 1050	720, 770
Direction of slope	S, SW	S, SW	E, NE	N, NE
Gradient (°)	10–40	10–40	20–60	20–40
Standing crop ($m^3\ ha^{-1}$)	>250	>250	>500	>640
Dominant tree species	*Quercus polycarpa*	*Q. cerris*, *Q. polycarpa*	*F. sylvatica*, *Abies alba*	*F. sylvatica*, *A. alba*
Crown closure	0.8–2.0	0.8–2.0	0.7–2.0	>2.0
Coarse woody debris (CWD) ($m^3\ ha^{-1}$)	20–30	20–40	150–280	250–350
Prevailing soil type	Eutric cambisol	Eutric cambisol	Dystric cambisol	Dystric cambisol
Leaf litter (g 300 cm^{-2}) (median ± med. abs. dev.)	82±28	80±29	124±30	99±28