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Preliminary results of a study on the soil mesofauna in disturbed spruce forest stands near Čertovo and Plešné Lakes in the Bohemian Forest (Czech Republic)

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Abstract. Soil arthropod communities were studied in disturbed spruce forest stands in the catchment areas of Čertovo (CT) and Plešné (PL) Lakes in the Bohemian Forest, in the Czech Republic. This study focused on changes in forest stands, including the soil environment, which occurred following windthrow and bark beetle outbreaks. Within the soil mesofauna, two main groups, Collembola and Oribatida were analysed in detail. Four different types of plots were selected for this study in both study areas: CT1 and PL1 stands – undamaged control forest stands, CT2 and PL2 stands – "dead" forest stands damaged by bark beetles, CT3 and PL3 stands – slightly managed windthrown forest stands left to natural succession, and CT4 and PL4 stands – harvested stands. Soil samples were collected in June, July and October 2012 from each treatment. Soil arthropods were subsequently extracted in a modified high-gradient apparatus in the laboratory over a period of seven days. The data included a total of 12,464 specimens of soil arthropods belonging to 17 groups collected from both study areas. In the Čertovo Lake study area the most abundant were Acarina, followed by Collembola and Heteroptera; in the Plešné Lake study area the most abundant were Acarina and Collembola, followed by Diptera. We recorded considerable differences in the Acarina and Collembola communities in the different plots. In both of the areas studied we recorded higher abundances in unmanaged than in the disturbed and managed stands. We conclude that the bark beetle outbreak and subsequent dieback of Norway spruce did not affect the soil mesofauna as much as traditional forestry practices.

Key words. windthrow, bark beetle, soil arthropods, Acarina, Collembola, Bohemian Forest.

INTRODUCTION

Disturbance is an important driver of variation in community structure and composition in most ecosystems. In addition, variations in the characteristics of the disturbance, such as frequency, size and severity, have a substantial effect on ecosystem properties and processes. A clear understanding of the mechanisms and effects of disturbance on ecosystems is therefore essential for interpreting current ecosystem structure, for devising effective strategies of ecosystem management and restoration, and for predicting ecosystem responses to future disturbances (Johnstone & Stuart Chapin III 2006). Windthrow is considered a natural driving force in the dynamics of forest ecosystems as it constitutes a sudden change in habitat by affecting structures, resources and microclimates (Wermelinger et al. 2003).

In most terrestrial ecosystems, Collembola are an important part of the soil mesofauna. In addition, soil mesofauna frequently includes mites, nematodes and enchytraeids, and also small millipedes, earthworms, ants, small gastropods, isopods and larvae of insects (Tebbe et al. 2006). Together with Oribatida, Collembola are often the major microarthropod constituents of soil. Microarthropods are an ecologically important group, which initiates the degradation of organic

material, e.g., they are abundant in the litter layer and enhance the cycling of carbon and nitrogen in soil (Cutz-Pool et al. 2007).

Since the 1990s a combination of mild winters, warm summers and storms has favoured the development of large populations of bark beetles (*Ips typographus*) in the Bavarian and Bohemian parts of the Bohemian Forest, which has resulted in large-scale dieback of Norway spruce (*Picea abies*) along the mountain range (Heurich et al. 2001, Jonášová & Prach 2004). Since then there have been several studies on the effect of bark beetle outbreaks and subsequent forestry management on soil microarthropods (Brůhova & Rusek 2005, 2006, Rusek & Brůhová 2007, Starý & Matějka 2009). In addition, in January 2007 the windstorm "Kyrill" damaged an area of almost 700,000 m^3 of spruce trees (Šantrůčková et al. 2010, Kindlmann et al. 2012). Because most of the affected plots were situated in unmanaged areas in the National Parks (catchments of Plešné, Čertovo and Laka Lakes), the damage was treated as a natural forest disturbance and traditional management practices (like preventive clear-cuts) were not generally applied, and all the forest biomass, including dead standing trees, remained on the plots.

The soil arthropod communities were studied in disturbed spruce forest stands in the catchments areas of Čertovo (CT) and Plešné (PL) Lakes in the Bohemian Forest in the Czech Republic. The study focused on the effect that windthrow and bark beetle outbreaks had on the forest, including the soil environment. Main aims of this study were: (1) to estimate the effect of natural and anthropogenic disturbances on soil arthropods; and (2) to assess the influence of different forest management upon Oribatida and Collembola, as main representatives of the soil mesofauna.

MATERIALS AND METHODS

There were four different treatments in both of the areas studied: CT1 and PL1 stands – of undamaged reference forest, CT2 and PL2 stands – of "dead" forest damaged by bark beetles, CT3 and PL3 stands – previously slightly managed areas of windthrown forest left to regenerate naturally, and CT4 and PL4 stands – freshly harvested areas of windthrown forest. The characteristics of these stands are:

CT1: 49° 10' 12.6" N, 13° 11' 16.7" E, 1,329 m a. s. l., NE facing on a 5–10° slope;
CT2: 49° 09' 46.4" N, 13° 11' 58.5" E, 1,065 m a. s. l., ENE facing on a 5° slope;
CT3: 49° 09' 59.9" N, 13° 11' 23.6" E, 1,277 m a. s. l., S facing on a 10° slope;
CT4: 49° 10' 10.3" N, 13° 12' 07.6" E, 1,056 m a. s. l., SSW facing on a 0–5° slope.

Thin brown podzolic soils with a moor soil of humus covering boulders commonly occurs in these stands. The forest is dominated by 90–150 year old Norway spruce with sparse fir and beech. The bedrock is predominately made up of mica-schist (muscovite gneiss) with quartzite intrusions (Veselý et al. 1998).

PL1: 48° 46' 33.0" N, 13° 52' 12.1" E, 1,143 m a. s. l., ESE facing on a 5–10° slope;
PL2: 48° 46' 43.4" N, 13° 51' 57.3" E, 1,132 m a. s. l., NNE facing on a 5° slope;
PL3: 48° 46' 34.7" N, 13° 51' 23.3" E, 1,316 m a. s. l., ESE facing on a 5–0° slope;
PL4: 48° 47' 24.2" N, 13° 51' 30.9" E, 1,062 m a. s. l., NE facing on a 5–10° slope.

Thin brown podzolic soils with a moor soil of humus covering boulders commonly occurs in these stands. The forest is on average 160 years old, dominated by Norway spruce (99%) with a few mountain ash and beech trees. The bedrock consists of granites (Veselý et al. 1998).

Soil samples were collected from each of four stands studied in June 2012 (CT1/PL1–CT3/PL3), July and October 2012 (CT1/PL1–CT4/PL4). The samples consisted of soil cores 3.6 cm in diameter (10 cm^2 in area) and 7–12 cm long (depending on soil depth). Five soil cores were collected at random using a steel corer from each of the research plot. The arthropods were extracted over a period of seven days in the laboratory using a modified high-gradient apparatus (Crossley & Blair 1991) and then determined to order level (in the case of the holometabolous insect orders Diptera, Coleoptera and Hymenoptera any larvae and adults present were counted separately). Finally, the soil arthropod communities recorded in the different treatments were compared.

RESULTS

In total 12,464 soil arthropods belonging to 17 groups were collected from the two areas studied, of which 7,861 belonging to 16 groups were collected from the Čertovo Lake (CT) study area

Table 1. Mean population densities [ind×m^{-2}±SE] of different groups of soil arthropods and mesofauna recorded in the Čertovo Lake study area. Mean values based on data from all four treatments

	June 2012	July 2012	October 2012
Araneae	–	150±166	200±141
Pseudoscorpiones	–	100±100	100±173
Chilopoda	67±94	50±87	50±173
Diplopoda	–	50±87	–
Symphyla	200±283	100±100	500 ±656
Heteroptera	3,600±2,628	1,300±1,300	3,250 ±3,465
Homoptera	133±189	–	250±218
Psocoptera	–	150±87	–
Thysanoptera	267±377	50±87	50±87
Diptera larvae	1,667±1,934	450±669	400±583
Diptera adults	333±340	50±87	–
Coleoptera larvae	200±163	500±300	200±245
Coleoptera adults	–	50±87	300±332
Hymenoptera adults	–	50±87	–
Acarina	94,867±49,574	84,000±50,200	124,000±72,361
Protura	200±163	450±456	150±87
Pauropoda	133±189	50±87	200±0
Collembola	25,933±13,379	34,150±13,447	46,000±12,391

(Table 1). The highest population density of arthropods was recorded in October (175,650 ind×m^{-2}), the next highest in June (127,600 ind×m^{-2}) and the lowest in July (121,700 ind×m^{-2}). The most abundant were Acarina, followed by Collembola and Heteroptera (Table 1). The highest total population density of mesofauna (Collembola and Acarina, which were mostly Oribatida) was recorded in the CT1 stand (214,900 ind×m^{-2}), with a slightly lower population density in the CT2 stand (185,300 ind×m^{-2}). Lower values were recorded in the CT4 stand (111,500 ind×m^{-2}) and the lowest in CT3 stand (66,300 ind×m^{-2}). A comparison of the different stands studied, based on data collected in July and October 2012, is presented in Fig. 1.

A total of 4,603 soil arthropods belonging to 15 groups were collected from the Plešné Lake (PL) study area. The highest total population density was recorded in June (149,533 ind×m^{-2}), with a slightly lower population density recorded in July (107,750 ind×m^{-2}) and the lowest in October (10,250 ind×m^{-2}). The most abundant were Acarina and Collembola, followed by a very much lower population density of larvae of Diptera (Table 2). The highest total population density of mesofauna (Collembola and Acarina, which were mostly Oribatida) was recorded in PL1 (81,800 ind×m^{-2}), with slightly lower values recorded in PL4 (67,500 ind×m^{-2}) and PL2 (52,000 ind×m^{-2}), and the lowest in PL3 (30,800 ind×m^{-2}). Changes in population density of the different groups of mesofauna in July and October 2012 are depicted in Fig. 2.

DISCUSSION

We expected to record higher population densities of soil arthropods in autumn (October) than in late spring/early summer (June, July), which is confirmed by the data collected for the Čertovo Lake (CT) study area, but not by that collected for the Plešné Lake (PL) study area, where population densities decreased dramatically in autumn.

There were considerable differences in soil mesofauna recorded in different treatments in the stands studied, especially in terms of the most abundant groups, the Collembola and Acarina.

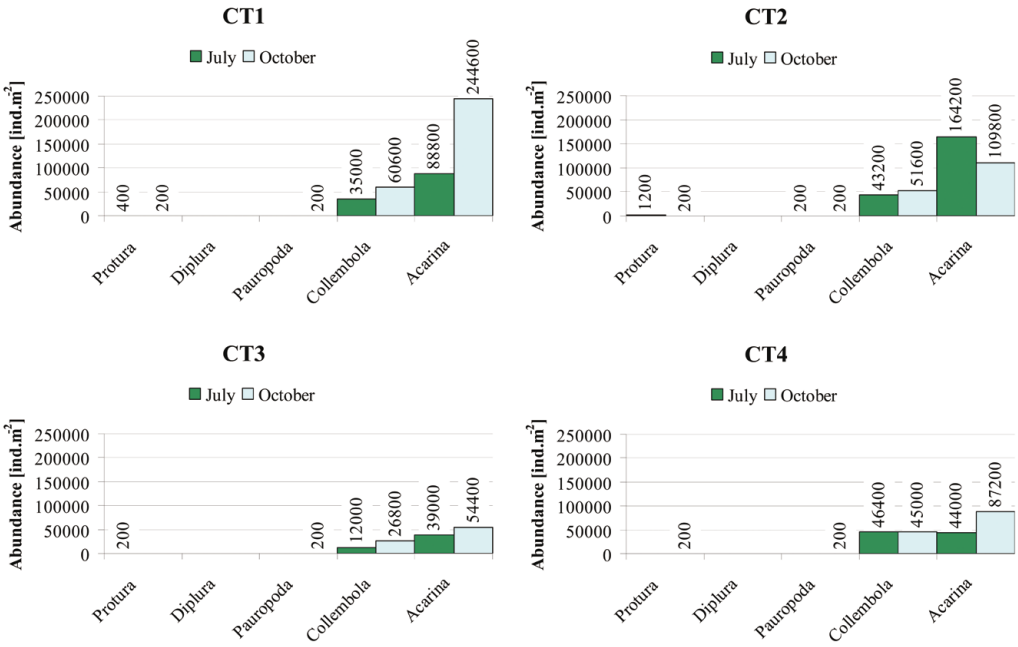

Fig. 1. Comparison of the population densities of the different groups of mesofauna recorded in July and October 2012 in forest stands subject to different treatments in the Čertovo Lake study area. For abbreviations of stands see text.

Table 2. Mean population densities [ind×m^{-2}±SE] of different groups of soil arthropods and mesofauna recorded in the Plešné Lake study area. Mean values based on data from all four treatments

	June 2012	July 2012	October 2012
Pseudoscorpiones	–	50±87	–
Chilopoda	–	50±87	50±87
Symphyla	–	300±332	50±87
Heteroptera	600±849	100±173	–
Homoptera	333±471	–	50±87
Psocoptera	67±94	100±100	–
Thysanoptera	–	50±87	–
Diptera larvae	1,933±2,594	400±490	–
Coleoptera larvae	200±283	600±316	50±87
Coleoptera adults	67±94	100±173	–
Hymenoptera larvae	67±94	–	–
Acarina	106,467±55,318	82,050±29,885	3,700±1,565
Pauropoda	–	150±260	–
Protura	600±849	300±224	–
Diplura	–	–	50±87
Collembola	39,200±22,628	23,500±13,279	6,300±4,369

This confirms previous results of Starý (2006), who studied the effect of different forestry management on Oribatida communities in climax spruce forests in another part of the Bohemian Forest, which was also attacked by bark beetles. According to his results, dieback of spruce does not significantly affect oribatid communities, unlike in areas where the forest is well managed, where the abundance and species richness of Oribatida are lowest. Similar, negative effect of clear felling on Collembola communities in the Bohemian Forest are also recorded by Rusek (2006). In both areas studied (CT and PL) we recorded much higher population density in unmanaged than disturbed and managed stands (except for the high abundance of Acarina in PL4 in July), with the lowest values recorded in previously managed windthrown stands that were left to regenerate naturally (CT3 and PL3). It is assumed that previous forestry practices caused changes in arthropod communities, while those in freshly harvested windthrown stands (CT4 and PL4) were still unaffected. This confirms previous results of Čuchta et al. (2009), which indicate clearing areas of spruce forests damaged by severe wind in the High Tatra Mts slightly enhanced the diversity of soil arthropod groups and species diversity of Collembola in the following year. Furthermore, Urbanovičová et al. (2010) report that harvesting windthrown trees dramatically affects the composition of epigeic arthropod communities and results in a considerable increase in the activity of several groups, i.e. Acari, Coleoptera of the family Scarabeidae and Aphidinea, as well as a striking increase in the activity of epigeic Collembola. This could account for the exceptionally high population density of Acarina recorded in July, which was higher than that recorded in "dead" forest stands damaged by bark beetle (PL2).

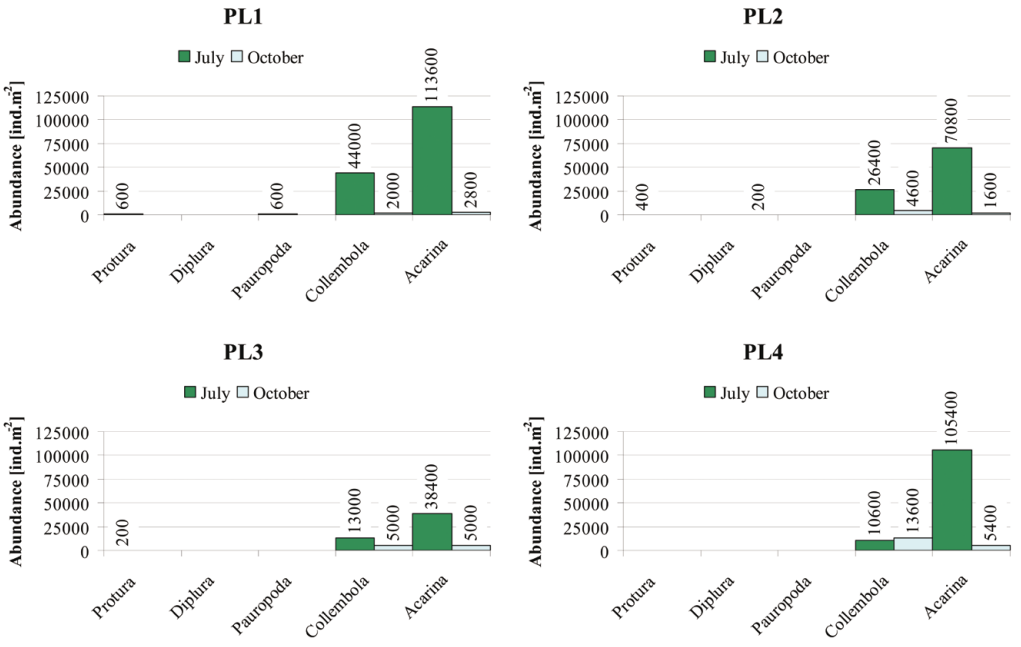

Fig. 2. Comparison of the population densities of the different groups of mesofauna recorded in July and October 2012 in forest stands subject to different treatments in the the Plešné Lake study area. For abbreviations of stands see text.

We conclude that bark beetle outbreaks and subsequent dieback of Norway spruce do not affect the soil arthropods as much as traditional forestry practices. This study is the introductory part of long-term research of soil arthropods, which may result in a better understanding of secondary succession in soil fauna in mountain spruce forests differently affected by natural and human disturbances.

A c k n o w l e d g e m e n t s

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