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Management intensity affects traits of soil microarthropod community in montane spruce forest

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ABSTRACT

This study examined the influence of forest management intensity (3 unmanaged, 3 mild managed, 5 intensively managed stands) on soil microarthropods in montane spruce forest. We particularly focused on Oribatida and Collembola which play important roles in organic matter decomposition and nutrient cycling. Our results showed a significant shift from fungivory and carnivory to detritivory in the Oribatida community accompanying management intensification. Similarly, parthenogenetic oribatid mite species contributed more to the community in intensively managed forests and the presence of Collembola species with developed furca increased with management intensification. Although there was no remarkable influence of management intensity on total densities or diversity indices, important and significant shifts in species composition and functional groups showed that soil functions and processes were affected by forest management. Trait assessment indicates a shift in roles Oribatida play in decomposition; fragmentation and comminuting of undecomposed litter seems to gain importance in the intensively managed forest, whereas fungivorous species affect primary decomposers through feeding on fungi in the unmanaged forest.

1. Introduction

Forest management affects the structure and function of the whole forest ecosystem; e.g. it simplifies and unifies the horizontal and vertical structures of the tree layer, changes understory vegetation and nutrient fluxes (Federer et al., 1989; Ferris et al., 2000; Grigal, 2000), and decreases the amount of dead wood (Fridman and Walheim, 2000). These changes include aboveground as well as the soil part of the ecosystem. The forest management usually conducted in the Central Europe results in even-aged, even-spaced monocultures of conifers. These practices include treatments, like thinning, planting of seedlings or clear-cutting, which result in disturbances to the system. It is important to understand the impacts of forestry practices to make forestry sustainable and maintain ecosystem functions and services.

In our study, we focused on the impact of forest management intensification on soil microarthropods, particularly Oribatida and Collembola. They have an important role in organic matter decomposition and nutrient cycling – two key processes of ecosystem functioning (Luxton, 1981) and are connected with primary decomposers through complex bottom-up and top-down effects (Marshall, 2000; Neher et al., 2012). In addition, soil fauna constitute a huge, often disregarded, reservoir of biodiversity. These microarthropods are the most abundant arthropods in forest soil and are considered to be efficient tools for biodiversity assessment (Deharveng, 1996).

We compared unmanaged natural spruce forests with mild- and intensively managed ones. The impact of management intensification on microarthropod community can be exhibited like changes in total density, diversity and species composition. Generally, diversity and species composition are more sensitive indicators compared with the total abundance. The measurement of total abundance was found to be insufficient to describe the recovery processes in soil (Lindberg and Bengtsson, 2006). Although total abundance was reported to decrease several years after clear-cutting by Blair and Crossley (1988), in other cases it was not affected (Hasegawa et al., 2013; Malmström, 2012). Thus, the detailed determination to the species level and a proper evaluation of changes in community is necessary.

In addition to this taxonomical approach, we focused on an assessment of functional traits. Such traits seem to be a sensitive indicator of community change. This "functional approach" is more focused on interactions and processes and facilitates the identification of general patterns and the synthesis of interdisciplinary knowledge (Vandewalle et al., 2010). We selected eight

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Table 1
Description of the Oribatida and Collembola traits.

Traits	Data type	Attribute
Oribatida		
Body size	Quantitative	in mm
Feeding guilds	Ordinal	1 = fungi and animals; 2 = fungi, in part litter; 3 = predominantly litter; 4 = algae and lichens
Reproduction mode	Binary	0 = parthenogenetic; 1 = sexual
Collembola		
Body size	Quantitative	in mm
Feeding guilds	Ordinal	1 = fungi; 2 = litter and fungi; 3 = litter and algae
Reproduction mode	Binary	0 = parthenogenetic; 1 = sexual
Furca presence	Ordinal	0 = absent; 1 = reduced; 2 = developed
Life forms	Ordinal	1 = euedaphic; 2 = hemiedaphic; 3 = epedaphic

morphological and life-history traits (sensu Violle et al., 2007; Table 1). We expected the "body size" and "life form" traits to reflect vertical distribution in the soil. "Feeding guilds" should provide insight into the roles in ecosystem functioning that the microarthropods fulfill. In reproduction mode, we were interested in an amount of sexual vs. parthenogenetic species. Parthenogenesis is generally assumed to facilitate establishment of populations (Norton, 1994) and fast recovery after disturbance (Lindberg and Bengtsson, 2005; Prinzing et al., 2002). On the other hand, sexual species were reported to be fast colonizers (Malmström, 2012). At the end, the development of furca and related jumping ability does not correlate with dispersal rate (Sjögren, 1997), but may protect animals from predators (Bauer and Christian, 1987).

We hypothesized that management intensity (1) will not affect the total abundance, (2) will affect diversity and species composition and (3) will affect the presence of species-specific traits, toward hemiedaphic, detritivorous, parthenogenetic species with increasing management intensity.

2. Methods

2.1. Site description

The study was carried out in the Boubín forest in the Šumava Mts. (Šumava National Park, Czech Republic; 48°58′N, 13°48′E). The area has annual precipitation of 1300 mm and an average annual temperature of 4 °C (Kubova hut' Meteorological station, 1003 m a.s.l.). The soil throughout the area is a dystric cambisol covering the gneiss bedrock (Albrecht, 2003).

Eleven forest stands were selected having different forest management intensities. The distance between the stands ranged from 200 m to several kilometres. Data about management intensity were taken from historic and recent forestry maps and tables, and through personal communication with the Šumava National Park Administration. We distinguished three levels of management: "No", "Mild" and "Intensive". "No management" forests (3 stands, mean altitude 1030 m a.s.l.) were heterogeneous in structure and age, with a coarse woody debris. At present, they are left to natural occurrence and have been without any forestry treatments in the last few decades. "Mild management" forests (3 stands, mean altitude 1060 m a.s.l.) were partly planted and partly naturally regenerated after the bark beetle attack and windthrow in the 1880s. Forestry practices (thinning etc.) were performed in the stands as usual. "Intensive management" forests (5 stands, mean altitude 1078 m a.s.l.) were planted on former spruce plantation stands in the 1940s and developed into typical even-aged spruce plantations. All stands were dominated by Norway spruce (*Picea abies*) with a minor occurrence of beech (*Fagus sylvatica*) and had an understorey formed mainly by *Vaccinium myrtillus*, *Calamagrostis villosa*, *Avenella flexuosa* and several mosses. Soil samples were taken in *C. villosa* patches in all stands.

2.2. Soil mesofauna sampling and chemical analyses

Soil microarthropods were sampled (10 cm^2, 8 cm depth) in all 11 forest stands in May 2008 (5 samples per stand) and at the beginning of November 2008 (5 samples per stand; in total 110 samples from both sampling dates). The samples were taken randomly in a range approximately 50 m within each stand. Soil arthropods were extracted in high-gradient MacFadyen funnels for 6 days. Oribatida and Collembola were extracted and identified to species level. When possible, oribatid juveniles were also identified, counted and added to the respective adults.

Chemical analyses were performed on the <2 mm fraction of the dried soil samples after microarthropod extraction. pH was determined in a 1 M KCl solution (3 spring + 3 autumn replicates in each forest stand). Total carbon and nitrogen contents were measured using a CN analyzer (NC 2100 Soil Analyzer, ThermoQuest Italia S.p.A.) in composite soil samples (consisting of five subsamples, 3 replicates per stand). Moisture was calculated as a difference between weights of fresh and dried soil samples (dried at 105 °C).

2.3. Data analyses

We used several indices to compare the microarthropod communities: species richness (species number per sample), Shannon's diversity index (H, using $\log_{10}$) and evenness ($E = H/\log(S)$; where S = total number of species in the community).

The community weighted trait means (CWM) were calculated as a mean of species trait attributes weighted with their relative abundance (sensu Makkonen et al., 2011). The species with unknown trait attributes were omitted from the trait assessment (their abundances are given in Figs. 3 and 4 and Supplementary Figs. 3 and 4).

The effect of management intensity on total density, indices and CWM values was tested with 2-way ANOVA (factors management and sampling date). Additional comparisons of means were performed with the Tukey HSD test ($p < 0.05$) when significant differences appeared. To avoid pseudoreplication, we analyzed the values averaged per experimental stand; i.e., for every forest stand we obtained two values (mean of five replications sampled in May 2008 and mean of five replications sampled in November 2008). Total densities of Oribatida and Collembola were log ($x + 1$) transformed to achieve normality and homoscedasticity. Densities of species did not achieve ANOVA's assumptions and therefore were analyzed with non-parametric Kruskal–Wallis test (data were averaged per stand; only 25 most dominant Oribatida and 25 most dominant Collembola species were tested). The significant level α was adjusted by using the false discovery rate procedure for multiple comparisons, which is known to optimize the power of multiple tests while controlling for the proportion of significant results that could actually be Type I errors (Benjamini and Hochberg, 1995).

3. Results

3.1. Soil conditions

The soil characteristics did not significantly differ by management intensity. Soil moisture ranged from 43% to 65% and pH was 2.8–3.1. N content (0.91%–1.68%) and C content (19.54%–38.63%) resulted in the C:N ratio ranging between 20.2 and 25.2.