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Spruce forest conversion to a mixed beech-coniferous stand modifies oribatid community structure

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ABSTRACT

We investigated oribatid mite community diversity and structure in the managed conversion of coniferous stands into semi-natural montane forests that are composed of a small-scale mosaic formed by different age classes of silver fir, Norway spruce and European beech in the southern Black Forest area, South-Western Germany, using the space-for-time substitution method. The core hypothesis was that changing tree composition and management practice will affect functional structure and diversity of oribatid mite community through changing substrate quality and litter diversity. Three forest districts were selected within the research region. Four stand types representing the major stages of forest conversion were selected within each forest district: (i) even-aged spruce monocultures, (ii) species enrichment stage, (iii) forest stand structuring stage, at which fur and beech and other deciduous trees penetrate the upper storey of the forest and (iv) a diverse continuous cover forest respectively. Oribatid mite abundance, species richness and composition, biomass, ecomorphs and feeding groups relative abundance were determined. An overall increase in species richness moving from the spruce monoculture to a continuous cover forest was detected. However, the herbivorous and litter-dwelling mites were most sensitive to forest conversion demonstrating significant differences in abundance between conversion stages. Almost all changes in the oribatid community were associated with the properties of the changing litter layer. Abundance of soil-dwelling mites remained very stable what is in contradiction with the response of the other soil fauna groups found at the same sites. Overall oribatid community seemed to be more dependent on total microbial biomass than fungi. However, observed effects were overshadowed by considerable district-induced differences.

1. Introduction

The replacement of native beech forests (*Fagus sylvatica*) by coniferous stands (*Picea abies* and *Pinus sylvestris*) leads to environmental problems in many regions of Central Europe (Ellenberg et al., 1986; Kazda and Pichler, 1998). Therefore, the idea of an ecologically sound forest management that aims at re-establishing mixed forests that are better adapted to site conditions became increasingly popular (Kazda and Pichler, 1998; Mendoza and Prabhu, 2001; Schou et al., 2012). Increasing tree species diversity and more complex vertical structure is claimed to strengthen sustainability of the whole system, accelerate carbon sequestration and to increase overall biodiversity through providing more ecological niches (Bengtsson et al., 2000; Gärtner and Reif, 2004; Dechene and Buddle, 2010; Wang et al., 2013).

The majority of forest biodiversity is hidden in the soil (André et al., 1994; Jeffery et al., 2010). Moreover, soil organisms play a key role in ecosystem processes such as litter mineralization, nutrient turnover and carbon sequestration. However, scientific evidence for significance and direction of forest conversion effects on soil biota is still surprisingly sparse and ambiguous (Elmer et al., 2004; Teuffel et al., 2005; Wardle et al., 2006; Chauvat et al., 2011). Different patterns of increase of certain fauna groups diversity and abundance (Elmer et al., 2004) or no effects at all (Wardle et al., 2006) were reported. It is assumed, that overall increase in the tree species diversity will help to maintain more diverse belowground communities (Cavard et al., 2011). However, this assumption is not always confirmed due to methodological problems associated with the enormous density and richness of soil-dwelling organisms, the small size of most soil biota and obscure taxonomy as well as not completely understood spatial microdistribution and food speciation (Donoso et al., 2010; Remen et al., 2010; Caruso et al., 2012), another important reason for absence of clear litter and soil fauna diversity coincidence are strong regional and subregional spatial

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differences in soil fauna response to forest stand conversion (Teuffel et al., 2005). Such spatial fluctuations may result from limited sampling effort, territorial historical reasons, localized contamination or even presence of biogeographic and landscape borders which overshadow forest conversion-related response of community parameters of soil fauna groups (Zaitsev and van Straalen, 2001; Zaitsev et al., 2013).

One possibility for resolving problems as defined above is using a model group within a set of spatially distant sites with similar conversion process running. Such group should be relatively easy to count and identify as a surrogate for overall soil biodiversity (Ekschmitt et al., 2003). Despite its numerous limitations and drawbacks this approach is widely used in biodiversity research (Gaston and Spicer, 2004). Oribatid mites (*Acari*: *Oribatida*) form a considerable part of soil decomposer community and contribute substantially to the total soil invertebrate species pool (Petersen and Luxton, 1982). They are often used as indicators for various management practices in all ecosystem types (e.g. Gulvik et al., 2008; Minor and Cianciolo, 2007). When using this group as an indicator, certain requirements for compatibility of the results should be met during the sites selection, including similar forest type in the beginning and the end of the forest conversion, similar mesoclimate, geology and slope exposure.

The aim of this study was to investigate the response of oribatid mites to the forest conversion process and potential spatial variability of this response. We investigated the managed conversion of coniferous stands into semi-natural montane forests that are composed of a small-scale mosaic formed by different age classes of silver fir, Norway spruce and European beech in the southern Black Forest area (Germany, MLR, 1999). The core hypothesis is that changing tree composition and management practice will affect functional structure and diversity of oribatid community through changing substrate quality and litter diversity.

We tried to reveal oribatid mite community response to the manual forest conversion and compare it with data for other soil taxa. The paper continues disclosure and discussion of results of extensive soil-ecological research performed in forests subject to conversion in this region. Data on soil macrofauna, nematodes and collembolans had been published earlier (Salamon et al., 2008; Salamon and Wolters, 2009; Chauvat et al., 2011).

2. Material and methods

2.1. Research area

The study sites are located in three adjacent forest districts (situated near settlements Schluchsee, St. Blasien and Gersbach) that form a 20 km Northeast to Southwest gradient in the southern Black Forest, Germany (Fig. 1). This region has primarily been formed by glacial processes and is characterised by high mountains and deep valleys (Liehl and Sick, 1980). Elevation ranges from 830 m to 1060 m a.s.l. Local geological condition vary between granite and gneiss bedrocks over very short distances. The soil type is a cambisol with signs of podsolization in the east (particularly Schluchsee). Depending on the underlying rock the soil texture varies from loamy to coarse. The mean annual precipitation is lower than 1800 mm (Schluchsee, St. Blasien) in the East and is about 2100 mm in the Western part of the study region (Gersbach; Reklip, 1995). The mean annual temperature ranges from 5 °C to 7 °C (Reklip, 1995). The potential natural vegetation is a *Luzulo-Fagetum* with *Abies alba* and *Picea abies*, interchanging with *Abieti-Fagetum* (Müller *et al.*, 1974).

Four stand types representing the major stages of manual forest conversion were selected within each forest district (cf. Teuffel et al., 2005): (i) even-aged spruce monocultures, (ii) species

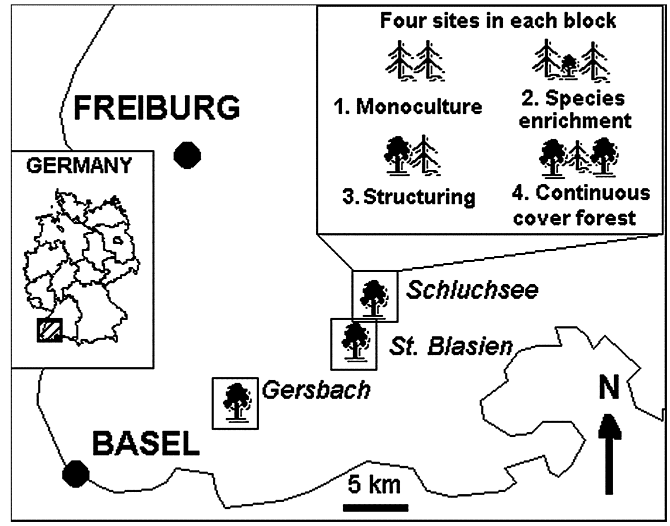

Fig. 1. Location of forest districts and arrangement of sampling sites in Southern Schwarzwald, Germany where soil samples were taken.

enrichment stage, at which fir and beech trees are planted in the understorey and spruce trees are manually thinned, (iii) structuring stage at which beech and other deciduous trees penetrate the upper storey of the forest and (iv) a diverse continuous cover forest respectively. They were similarly aged and treated across all three districts with liming approximately 10 years after beech trees introduction (Gärtner and Reif, 2004). Thus, three replicate sites were available for each of the four conversion stages. The four stages will be abbreviated in the following text to C1, C2, C3, and C4, respectively. C2 results from introducing a mixture of tree species into forest gaps cut into C1. An additional age component is introduced into C3 by promoting the formation of unevenly-aged *Fagus sylvatica*, *Abies alba* and *Picea abies* trees via structuring, ongoing thinning and selective logging. C4 has developed from C3 and now forms a well-structured mixed stand composed of three tree species mentioned above. The response of the ground vegetation to forest conversion varies with site conditions (Gärtner, 2003). The transformation process increased the structural diversity of the stands, but is accompanied by a slight decline in the species richness of the ground vegetation (Gärtner and Reif, 2004).

2.2. Samples collection, processing and mites identification

Sampling was performed three times, in September 2001, May 2002 and October 2002 at each sampling site. A single soil core (diameter: 5 cm) was taken by means of steel corer from each of three randomly selected 2 m × 2 m areas within 100 m^2 subplots situated in the centre of each site. In total for all three seasons 9 soil cores were obtained at each site. The cores were split into two parts in the field: organic layer, including litter and fermentation horizons and mineral horizon (uppermost 5 cm). Soil microarthropods were extracted from the intact soil cores using a modified Macfadyen high-gradient canister method, with the temperature gradient stepwise increasing from 20 to 60 °C within 15 days. After collecting the extracted animals in ethylene glycol, all oribatid mites were transferred into 90% alcohol and counted. Whenever possible, nymphs and larvae were also identified to species and added to the respective adults. When this was not possible, they were counted separately as 'unidentified nymphs and larvae' (see Appendix A).

Data for water content, pH, stone content, thickness of the organic layer, loss on ignition, were estimated from the soil samples