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Global warming affect Collembola community: A long-term study

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Summary

Long-term (1992–2002) effects of climate changes on soil Collembola in Scots pine *Pinus sylvestris* forests in North Vidzeme Biosphere Reserve (northern Latvia) are investigated. The study was carried out in three forest stands of different age, young (30–40 years), middle aged (50–70 years), and old (150–200 years). One hundred soil samples were collected within each sampling site once a year in autumn over a period of 11 years. In total, 66 species of Collembola were found. Species richness varied between 47 and 56 and density of Collembola from 7300 to 8300 ind m^{-2}. A statistically significant increase in the sums of positive air temperatures ($\geqslant 4\,^{\circ}C$) was recorded during the period of investigation. Precipitation and thereby soil moisture showed considerable year-to-year fluctuations. Non-metric Multidimensional Scaling of the data yielded two axes explaining 48.6% and 38.6% of the variation. Axis 1 coincided with the trend of sums of positive air temperature ($r = 0.66$). Axis 1 corresponded best with the negative impact of warming of climate on Collembola, mainly on the euedaphic species inhabiting the deeper layers of the organic soil horizon. Axis 2 was considered reflecting the effect of soil moisture fluctuations (correlation with moisture $r = -0.62$) on litter dwelling, mostly hemiedaphic Collembola. Species richness tended to decrease gradually in all forest sites during the study period from 29–36 to 13–26 species. Correlation between axes ($r = 0.455$) indicated interaction effects between positive air temperatures and soil moisture. Forest age showed no substantial effect on the community structure, therefore the changes observed cannot be explained by ecological succession.

Introduction

The soil fauna plays an important role in soil formation and maintaining its fertility (Coleman and Crossley 1996). Therefore, it should be regarded as one of the ecosystems' components

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deserving special attention in connection with climate warming. However, there are very few studies on the effects of climate warming on soil fauna until recently (see review in Lindberg 2003). Several of them have included Collembola as a model group (Rusek 1993; Hodkinson et al. 1998; Coulson et al. 2000; Frampton et al. 2000; Juceviča and Melecis 2002; Lindberg et al. 2002; Pflug and Wolters 2002; Lindberg 2003; Lindberg and Persson 2004) because of their high sensitivity to environmental factors and soil disturbance (Hopkin 1997).

Two climatic variables, precipitation and mean temperatures, were the main factors considered by studies of climate warming effects on biological communities. Most of the studies performed on Collembola focused on experimentally simulated drought effects (Frampton et al. 2000; Pflug and Wolters 2001; Lindberg et al. 2002; Lindberg 2003) resulting in a decrease in abundance and species diversity. This is in concordance with data from our long-term study of pine forest soils (Juceviča and Melecis 2002).

Less information is available on the long-term effects of rising temperatures on Collembolan communities and the existing data are mainly from northern latitudes (Kennedy 1994; Hodkinson et al. 1998; Coulson et al. 2000) or high mountain regions (Rusek 1993). The only data from the temperate zone are those of Wolters (1998) on long-term dynamics of collembolan community in a German beech forest. He found positive correlations of Collembola abundance with the mean temperatures of the previous year.

In our earlier studies (Juceviča and Melecis 2002), as well as in climate change simulation experiments from Sweden (Lindberg 2003), temperature rise was strongly correlated with a decrease in moisture, therefore it was not possible to distinguish between effects of both factors.

In Latvia, warming of the climate has been documented by a statistically significant increase of mean temperatures during the last decades (Lizuma 2000; Kļaviņš et al. 2002). Significant increase of mean annual air temperatures during the last 10-year period has been documented in the Baltic region (Golberg et al. 2003).

The aim of this paper is an analysis of long-term effects of climate warming, in particular interactions of temperature and precipitation, on Collembola community of a pine forest soil of the temperate zone. Investigations have been performed in Latvia during a 11-year period between 1992 and 2002, when statistically significant increase in sums of positive air temperatures was recorded, while precipitation fluctuated from year-to-year.

Because both climatic variables, temperature and precipitation, also affect soil moisture conditions and hence living organisms, a multidimensional analysis was used to partition temperature effects from the background of fluctuations of precipitation.

Materials and methods

Field site

Sampling of soil Collembola communities has been performed within three monitoring sites established near Mazsalaca in North Vidzeme Biosphere Reserve (latitude 57°53′N, longitude 24°59′E). Three forest sites were selected in a *Pineto-hylocomiosa* community with different site age: a young stand, 30–40 years old, a middle aged stand, 50–70 years old, and an old stand, 150–200 years old (hereafter indicated as Y, M and O, respectively). More details on the soil and the vegetation of the study sites are given by Juceviča and Melecis (2002).

Sampling and species identification

Soil samples for investigation of soil Collembola were collected once a year, at the end of August in 1992–2002. At each forest site Collembola were sampled taking 100 soil cores (2.5 cm diameter, 10 cm depth). Extraction of Collembola was performed using a modified high gradient extractor. Detailed description of sampling design and extraction of soil animals as well as determination of soil moisture are given by Juceviča and Melecis (2002). Sums of positive air temperatures ($\geqslant 4\,^{\circ}$C) were calculated from mean decade temperatures of the year. Mean temperatures and precipitation were calculated from May–August meteorological data of a local weather station.

Collembola were identified to species level in most cases. The taxonomy followed Fjellberg (1980, 1998), Babenko et al. (1994), Bretfeld (1999) and Potapov (2001). Extracted species were grouped into life forms according to Stebajeva (1970).

Statistical analysis

Non-metric Multidimensional Scaling (NMS) (Kruskal 1964; Mather 1976; McCune and Grace 2002) was used for ordination of log-transformed Collembola density data using PC-ORD (McCune and Mefford 1999). The data matrix contained 66