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Species abundance distribution of collembolan communities in forest soils polluted with heavy metals

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Abstract

The species frequency of collembolan communities along a gradient of heavy metal pollution in soil of pine forest soils was studied. Sampling plots were established in forests 1, 3, 5, 8, 11, 68 and 148 km from the Miasteczko Śląskie zinc smelter. At each plot the plant associations, physicochemical characteristics of soil, and collembolan species composition and abundance were examined. The structure of collembolan communities was analyzed with regard to species distribution, testing geometric series, broken-stick, logarithmic series, log-normal and negative binomial distribution models. Most of the collembolan communities occurring both in contaminated and in uncontaminated soils had structure similar to a negative binomial distribution. In the samples from the oldest forest, the species frequencies could also be fitted to a log-normal distribution. The species frequency model was independent of the degree of soil pollution. Under the assumption of a negative binomial distribution of Collembola from soil samples, it is possible to estimate the theoretical number of collembolan species in the habitats studied. The difference between estimated and empirical numbers of species (the number of species not revealed in samples) was linearly correlated with metal concentrations in soil, indicating the elimination of a number of rare species from severely polluted forests.

Keywords: Collembola; Species frequency models; Pine forest; Heavy metals; Soil pollution

1. Introduction

Much concern has been expressed about the effects of pollutants on Collembola in the field. Pollution might be expected to decrease populations of all species of Collembola, but sometimes the numbers of certain species increase under inter-

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mediate levels of pollution (Hopkin, 1997). Preferred species of fungi may also grow better (Hågvar, 1990); and some species of Collembola may benefit from reduced competition with less tolerant species. The sensitivity to metal pollution of some populations of springtails was studied by Bengtsson and Rundgren (1988), who found that neither richness, density nor diversity was linearly correlated with metal concentrations, but showed a bell-shaped distribution instead. Differences in sensitivity between species were noted: *Folsomia fimetarioides* became the dominant species in polluted soil and seemed to have a distribution inversely related to that of *Isotomiella minor*. Tranvik and Eijsackers (1989) showed that *F. fimetarioides* had a higher preference for metal-tolerant fungi than *I. minor*. The ability of *F. fimetarioides* to choose fungal species and to avoid metals explains its dominance over *I. minor* in polluted soils. Gillet and Ponge (2003) observed changes in species assemblages of Collembola along a gradient of metal pollution in a field planted with poplar 20 years previously in France. The increase in abundance of the whole collembolan community under intermediate levels of pollution was due mainly to *Mesaphorura macrochaeta*, the gut contents of which indicated that it had avoided the root mat and fed mainly in the mineral soil beneath.

Hågvar (1994) proposed examination of deviations from a log-normal distribution in the species dominance of microarthropod communities as an indicator of stress. He found that the log-normal dominance structure of Collembola and Oribatei showed characteristic changes when the communities were stressed by acidification, heavy metal load or soil tillage. The log-normal curve of the undisturbed community first became flattened under increasing stress intensity because the most susceptible species moved towards the lower dominance class while some more tolerant species became more dominant. At higher stress intensity the log-normal distribution became strongly left-skewed because the sensitive species became very rare. Finally, when these sensitive species were lost, a new log-normal distribution might appear. Hågvar (1994) suggested that the observed changes in dominance structure could serve as an early warning for stressed microarthropod communities.

Are deviations from the species frequency model a general occurrence under stress? If so, collembolan communities sampled along a gradient of heavy metal pollution should show shifts in species distribution. This study examines the abundance structure of species in collembolan communities occurring in natural pine forests and analyses changes in structure in relation to the degree of heavy metal pollution of soil.

2. Materials and methods

2.1. Study area

The selected study sites were in forestry districts at the following distances from the zinc and lead smelter in Miasteczko Śląskie: 1 km (Żyglinek district), 3.5 km (Zwierzyniec district), 8 km (Zielona district) and 11 km (Dyrdy district); and in forests located beyond the reach of the zinc smelter emissions at distances of 68 km (Motyczno district) and 148 km (Błota district) (Fig. 1). There are no other known sources of heavy metal pollution within 148 km of any of the sites.

Phytosociological similarity (vegetation type) and physical characteristics were taken into account in selecting study sites along the soil pollution gradient. The sites were surveyed by the Braun-Blanquet (1964) method and phytosociological units were determined according to the following classification:

- Class: Vaccinio-Picetea Br.-Bl. 1939
- Order: Cladonio-Vaccinietalia Kiell. Lund 1967
- Association: Leucobryo-Pinetum
- Subassociation: *Melampyrum pratense Dryopteris carthusiana*

The selected forest association represents habitats of two fertility types in Leucobryo-Pinetum forest: poor (subassociation *M. pratense*) and fertile (subassociation *D. carthusiana*). The vegetation also differed between these two habitats. Phytocenoses with *M. pratense* in Błota, Dyrdy and Zielona districts were floristically poor (8–18 species in the sample) and distinguished by a large contribution of *Vaccinium vitis-idaea*. Phytocenoses representing the *D.*