Distribution patterns of Collembola affected by extensive grazing in different vegetation types

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Abstract
The effect of extensive grazing on Collembola communities was studied in different vegetation types of National Park Neusiedler See – Seewinkel (Austria). The results showed that the effect of extensive grazing leads to differences considering soil temperature, bulk density and organic matter content. The total Collembola material included 6338 specimens belonging to 20 euedaphic and eight hemiedaphic species. Significantly higher values of total species richness and abundance of hemiedaphic species were recorded at grazed plots in comparison to ungrazed plots. However, Collembola species number was correlated positively with plant species richness and collembola density was correlated positively with organic matter content and soil temperature. The ratio of euedaphic to hemiedaphic species was negatively related to bulk density and positively to plant species richness. Canonical correspondence analysis based on collembolan communities belonging to different vegetation types suggests separate trends for grazed and ungrazed plots. The main environmental factors correlated with the changes in collembolan communities were plant species richness and soil bulk density.

Key Words
Microarthropods, life forms, land-use, grasslands.

Introduction

An effective way of land-use, extensive grazing by large herds of cattle in the National Park Neusiedler-See Seewinkel, eastern Austria, was studied. Unfortunately it disappeared for economic reasons by the 1960s and was re-established only in 1987 as a management practise for conservation of the remaining dry to sub-humid grasslands. Extensive grazing results in high structural heterogeneity by browsing, trampling and nutrient in- and outputs in the habitat (Fischer *et al*. 1996). Moreover, livestock grazing influences plant-community structure, soil temperature, moisture and soil compaction and is also likely to effect directly or indirectly the populations and diversity of soil biota (Bargett and Wardle 2003; Clapperton *et al*. 2002; Merill *et al.* 1994; Peterson *et al.* 2002). Collembola are among the most ecologically diversified microarthropods occurring in high abundances in grasslands. They play an important role in plant litter decomposition processes (Anderson *et al.* 1983; Faber *et al.* 1992) and in forming soil microstructure (Dunger 1983). The relatively large population sizes and potential influence on nutrient mobilization make suggests that they represent a key group for determining system's productivity.

In the present study, we examined the effects of extensive cattle grazing on collembolan communities in five different vegetation types. Moreover, we analysed how different ecological life forms (euedaphobionts and hemiedaphobionts) reacted to extensive grazing mirroring the severity of disturbance caused by grazing in different soil depths. The main questions of the present study were: How do euedaphic or hemiedaphic species respond to grazing? Which main habitat parameters influence the distribution of Collembola communities in grazed and ungrazed grasslands?

Methods

Site description
The investigation was performed in the National Park Neusiedler See – Seewinkel, about 40 km southeast of Vienna, Austria (45°46'N, 16°47`E).The study area represents sandy salt-effected chernosems with low nutrient status. The diversity, density and community structure of Collembola were investigated at two adjacent plots, one of which has been extensively grazed by cattle from May to October for 20 years (W-G). The investigated pasture was managed with low grazing intensity (<2 BCU/ha). The second plot was an ungrazed, densely vegetated exclosure (W-U).

Both grazed and ungrazed plots were characterized by five vegetation types of different plant species richness growing along the dry-to-wet gradient:

W1-species rich semi-dry grassland (*Carici stenophyllae- Festucetum pseudovinae)*,
W2-salt-effected and periodically flooded grassland (*Centaureo pannonici-Festucetum pseudovinae*),
W3-species poor reed area (*Scorzonero parviflorae-Juncetum gerardii, Scirpetum maritimi*),
W4-species poor *Agrostis* grassland (*Scorzonero parviflorae-Juncetum gerardii*, *Scripetum maritimi*),
W5-*Puccinellia* grassland (*Atropidetum peisonis*);

Collembola sampling
In April, July and September 2005, 10 soil cores of 10 cm^2 in soil surface and 10 cm deep were taken from each of the vegetation types of grazed and ungrazed sites. Collembola were extracted using Tullgren funnels, counted and determined to species level. To examine whether Collembola species in different soil depths are differently affected by extensive grazing Collembola were classified to hemiedaphic species (living in the litter and in upper layers of the humus horizon) and euedaphic species (particularly living within the soil) after Rusek (2007).

Data analysis
We used pair/sampled Wilcoxon-Tests to compare the grazed and the ungrazed sites regarding abiotic parameters (phosphate, nitrate, pH, organic matter content, soil temperature, bulk density and plant species richness) and Collembola parameters (species richness, total number of individuals). In order to assess the influence of abiotic parameters on Collembola parameters (species richness, total number of individuals, ratio euedaphic:hemiedaphic species and individuals, respectively) stepwise multiple regression analyses were conducted. Response variables were tested for normality with Shapiro-Wilk test and log/transformed when necessary to meet criteria for statistical analysis. The number of variables to enter a regression model was limited to two in order to avoid problems related to overfitting. We used an ordination method (Canonical Correspondence Analysis, CCA) to check for the influence of environmental factors on the species composition of the Collembola communities.

Results
Environmental variables
The effect of extensive grazing leads to significant differences considering soil temperature, bulk density and organic matter content. Soil temperature at the ungrazed plots was considerably higher by 3% than at the grazed plots ($P = 0.043$) Furthermore, bulk density was respectably higher by 8% at the grazed plots than at the ungrazed plots ($P = 0.043$). On the other hand, organic matter content at the grazed plots significantly exceeded by 24% tthat of the ungrazed plots ($P = 0.043$). Plant species richness was higher on grazed plots than on ungrazed plots but the difference was only marginally significant ($P = 0.66$).

Collembolan diversity
A total of 6338 specimens belonging to 20 euedaphic and eight hemiedaphic species of Collembola were obtained from the ungrazed and grazed plots. Total diversity was considerably higher at the grazed plots than at the ungrazed plots ($P = 0.039$).The total abundance of Collembola varied between 26,000 ind./m^2 on grazed plots and 16,200 ind./m^2 on ungrazed plots but differences were not significant. Considering the diversity of both collembolan life forms only hemiedaphic species reached remarkably higher densities at the grazed site ($P = 0.043$).

Total species richness of Collembola was increased by means of the number of plant species ($r^2 = 0.630$, $P = 0.006$). Collembola density was positively correlated with the amount of organic matter ($r^2 = 0.434$, $P = 0.038$) and soil temperature ($r^2 = 0.468$; $P = 0.029$). The ratio of euedaphic to hemiedaphic species was negatively related to bulk density ($r^2 = 0.609$, $P = 0.008$) and positively to plant species richness ($r^2 = 0.561$, $P = 0.013$); i.e. that the number of hemiedaphic species increased relative to the number of euedaphic species with increasing bulk density and decreased with increasing plant species richness. This shift was mainly caused by changes in euedaphic Collembola diversity: the number of species of this life form increased with plant species richness and soil organic matter ($r^2 = 0.882$, $P = 0.001$; plant species richness: partial $r^2 = 0.770$, soil organic matter: partial $r^2 = 0.112$) and declined with increasing bulk density ($r^2 = 0.590$, $P = 0.009$) while hemiedaphic species richness appears to be unaffected by bulk density and all other environmental variables (all P-values > 0.05).

The CCA analysis (Figure 1) revealed a clear differentiation between the Collembola communities of the different vegetation types and of grazed and ungrazed plots. The first canonical axis, which explains 32.2% of variation in the species data, was primarily determined by plant species richness but also by soil bulk density. Moreover, the latter was also correlated with the second canonical axis (19.9% explained variation). The model gained from forward selection containing both variables; plant species richness and soil bulk density, explained 53.1% of the variation in the Collembolan species data ($P = 0.001$).

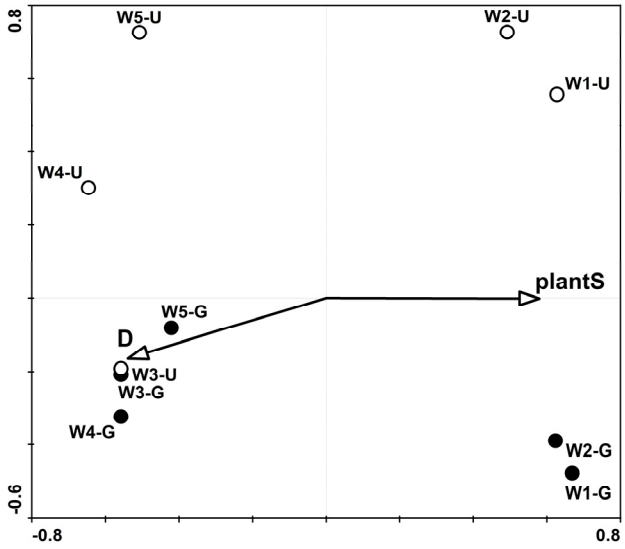

Figure 1. CCA biplot based on collembolan communities in different grazed (W1-G to W5-G) and ungrazed (W1-U to W5-U) vegetation types and environemental factors bulk density (D) and plant species richness (plantS).

Discussion

We found that extensive grazing had considerable influence on habitat parameters but also on collembolan communities. Grazing treatment significantly affected soil water content, soil temperature and bulk density. The results of a higher amount of organic matter at grazed plots could be attributed to the fact that livestock trampling can induce pressing of the dead plant and old grass material to the soil surface and therefore advancing a dense sward (Nitsche and Nitsche 1994). Species richness of Collembola was remarkably higher at grazed plots than at ungrazed plots. Extensive grazing represents a low-input system with increased habitat and resource heterogeneity resulting in a more diverse fauna (Morris 2000; Clapperton *et al*. 2002).

According to the present study significant correlation between Collembola abundance and grazing effect was found for hemiedaphic species, which developed respectably higher densities at grazed plots. We have found that Collembola density is positively correlated with organic matter content which agrees with other studies (Curry 1987; Eaton 2004). Most of the euedaphic species which reacted negatively to the higher bulk density are more sensitive to disturbance by trampling and compaction of the soil than hemiedaphic species are. Hemiedaphic Collembola seems to be more tolerant to drought, trampling and other disturbances caused by livestock grazing.

CCA results show that the collembolan community structure differs depending on the presence or absence of livestock grazing. The main environmental factors correlated with the changes in collembolan communities are the plant species diversity and bulk density.

Conclusions

Extensive grazing has considerable influence on habitat parameters and on distribution of Collembola as well. The effect of grazing induced increase in species richness of total Collembola. Separate trends in Collembola life forms were suggested for grazed and ungrazed plots. The number of plant species, the amount of organic matter,bulk density and soil temperature were the most important of the measured habitat parameters at grazed and ungrazed plots that correlated with density and diversity of Collembola. Extensive grazing as suitable land-use has a strong impact on Collembolan communities as well as Collembola life forms as a group.

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