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Distribution and diversity patterns of soil fauna in different salinization habitats of Songnen Grasslands, China

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ABSTRACT

The soil fauna communities were studied in the Songnen Grassland, which is located at the easternmost Eurasian steppe of northeast China. We sampled sites from May to October with different alkaline contents to investigate the salinization process on soil fauna. We found that the dominant groups were Prostigmata, Oribatida, and Gamasina mites and the collembolan families Isotomidae and Entomobryidae. Results showed that the composition of the soil fauna communities differed significantly among the habitats with different salinity. Number and density of taxa were lower in communities with high salinity. The highest number of taxa (66) was found on the *Artemisia anethifolia* sites, the lowest number (47) on the Alkali patches. The Shannon-Wiener index was the lowest on the Alkali patches, whereas the Simpson-dominance index was the highest in these habitats. The number and density of taxa changed during the seasons. The soil fauna tended to gather on soil's surface. According to the Redundancy analysis, the soil organic matter positively affected the density of the soil fauna and soil fauna decreased with increasing degree of salinization in Songnen Grasslands.

1. Introduction

Grassland degradation has the phenomena that grass struggles to grow or can no longer exist on a piece of land due to causes such as overgrazing, climate change and soil salinization (Akiyama and Kawamura, 2007). Soil salinization, one of the major causes of grassland degradation, has received wide attention nowadays. It affects plant growth and distribution by changing the material composition of the ecosystem (Agnieszka, 2003; Cole et al., 2006; Dehaan and Taylor, 2002; Jobbágy and Jackson, 2004), resulting in decrease of biological production. Previous study have revealed that, soil salinization could have a significant impact on belowground systems through changing soil organic matter or base saturation (Wu et al., 2013; Rousk et al., 2011), and these effects should not be neglected. Soil fauna, as an important component in grassland, play a significant role in nutrient cycling and energy flow (Noble et al., 2009; Patricia et al., 2012; Xin et al., 2012), mainly by regulating the composition, distribution, seasonal change of soil microorganisms (Pablo et al., 2013; Song et al., 2008; Yin et al., 2010). Soil fauna is also an important indicator of grassland degradation (Maurizio et al., 2007). Previous studies have been shown that, if soil environmental changes such as moisture or nutrients exceeded limitation of the body adaption and regulation, soil fauna's survival and reproduction could be affected (Yan et al., 2012). Consequently, it is of concern to understand the distribution pattern of soil fauna communities in the grassland.

Currently, majority of current studies regarding grassland degradation focus on overgrazing, burrowing of small mammals, and climate change (Arthur, 2007; Li et al., 2012; Xie and Sha, 2012). The studies of soil salinization in grassland degradation are relatively rare. Structure and diversity of soil fauna communities are different by different grassland ecosystems and the same ecosystem of different degrees of degradation (Yeates et al., 1997). Soil fauna, as a crucial indicator of environmental changes, is sensitive to soil salinization. However, few studies regarding the effects of grassland soil salinization on soil fauna distribution have been conducted.

To better understand the effects of different salinization on soil fauna distribution and diversity pattern, we selected the salinization habitats of the Songnen Grasslands in this study, where soil salinization was severe (Li and Zheng, 1997). Soil fauna were collected in the different salinization habitats including *Chloris virgata*, *Suaeda corniculata*, *Puccirellia tenuiflora*, *Artemisia anethifolia* and Alkali spot habitat. We addresses three questions: for habitats with different degrees of

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salinization (1) what are the respective composition and diversity of soil fauna? (2) What are the respective spatial and temporal distributions of soil fauna? (3) Which environmental factors impact the soil fauna?

2. Materials and methods

2.1. Study area

The study site is located at the Yaojingzi, in the southern Songnen Grasslands, Jilin Province, northeastern China (44°40′–44°44′N, 123°44′–123°47′E). The area has a sub-humid continental monsoon climate, with a mean annual temperate of 4.9 °C and mean annual precipitation of 470 mm, mainly concentrated in June to August. The ≥10 °C accumulated temperature is 3000 °C, with a frost-free period of 136–150 d. The warmest monthly average temperature is 22–25 °C while the coldest month average temperature is −16 to 22 °C. The main soil types in the study area include light chernozem soil, saline meadow soil, alkaline meadow soil, alkaline saline soil and chernozem type sand soil (Zhu et al., 2010). The landscape plant community is *Leymus chinensis* community. The natural grasslands of the Songnen Grasslands are still given priority to for grazing. However, soil salinization is greatly related to grazing. Due to excessive grazing, the soil salinization degree there has been aggravated. According to the salinization degree and the different dominant species, the main plant communities are the *Chloris virgata*, *Suaeda corniculata*, *Puccirrellia tenuiflora* and *Artemisia anethifolia* habitats.

2.2. Field methods

To analyze the distribution pattern of on soil fauna in different salinization habitats, five habitats were selected. The salinization degrees from low to high were as follows: *Chloris virgata* (I), *Suaeda corniculata* (II), *Puccirrellia tenuiflora* (III), *Artemisia anethifolia* (IV), and Alkali spot (V) (Table 1).

Soil samples were collected from May to October, which corresponded to the main periods of the soil fauna activity in the study site. Four quadrats were randomly established at 5 m intervals. In each quadrat, soil macrofauna samples were collected from the litter layer (50 × 50 cm) and one soil core (50 × 50 cm), and the soil core was divided into 3 layers (0–10, 10–20 and 20–30 cm) in the each month. All litter and soil cores were thoroughly hand-sorted, and all soil macrofauna were collected into vials. A total of 360 soil macrofauna samples were collected (5 habitats × 1 plot × 4 quadrats × 3 layers × 6 sampling periods). Modified Tullgren funnel extractors were used for collecting the soil mesofauna. The samples extracted were collected from the litter layer (10 × 10 cm) and one soil core (10 × 10 cm), and the soil core was divided into 3 layers (0–10, 10–20 and 20–30 cm) as well. These samples were taken back to the laboratory and extracted for 24 h at 40 °C. A total of 360 soil mesofauna samples were collected (5 habitat s × 1 plot × 4 quadrats × 3 layers × 6 sampling periods). All of the soil fauna samples were preserved in 75% alcohol. The soil fauna were counted under an OLYMPUS SZX16 stereoscopic microscope (Olympus Co., Tokyo, Japan), and identified by order or family levels.

Table 1
Characteristics of different salinization degrees in each habitat.

	Different salinization habitats				
	Chloris virgata	*Suaeda corniculata*	*Puccirrellia tenuiflora*	*Artemisia anethifolia*	Alkali spot
Soil salinity (%)	0.19%	0.26%	0.47%	0.68%	1.12%
Agrotype	salinized meadow soil	salinized meadow soil	saline-alkali soil	saline-alkali soil	saline-alkali soil
Constructive species	*Chloris virgata*	*Suaeda corniculata*	*Puccirrellia tenuiflora*	*Artemisia anethifolia*	–
Accompanying species	*Suaeda corniculata; Puccirrellia tenuiflora*	*Puccirrellia tenuiflora; Artemisia anethifolia*	*Artemisia anethifolia*	*Puccirrellia tenuiflora*	–

The natural moisture content and soil organic matter are important indexes of the soil physical and chemical properties, and pH is an important index of soil salinity. Therefore, when the soil fauna were sampled, each sample of soil was placed in an aluminum box for determination of soil moisture content (SMC). At the same time, a certain number of soil samples were collected for the determination of soil organic matter (SOC) and pH value.

In the laboratory, the aluminum boxes were oven-dried at 105 °C for the determination of soil moisture content (SMC). The soil samples were air-dried, foreign bodies were removed, and then the samples were ground. Soil pH value was determined by potentiometry (PHS – 3B precision pH meter). The potassium dichromate method was chosen for the measurement of SOC. The calculation results are shown in Table 2.

2.3. Data analysis

The data of soil macrofauna and soil mesofauna were combined, and the results were converted into numbers per square meter (Ind/m^2).

The determination of soil fauna communities diversity indexes used the following formula: Shannon-Wiener index: $H' = -\sum_{i=1}^{s} Pi \ln Pi$; Margalef richness index: $D = \frac{S-1}{\ln N}$; Pielou evenness index: $e = H'/\ln s$; Simpson dominance index: $c = \Sigma(Ni/N)^2$.

Repeated ANOVA measurements were carried out to evaluate the effects of habitat, sampling period and their interactions at the group number and density. One-way analysis of variance was then used to determine the differences in group number, density of soil fauna among habitats, sampling periods and sampling depths, and the difference of diversity indexes among the habitats and sampling periods. Multiple comparisons of means were performed at the 5% probability level using least significant difference (LSD) when the differences were significant. To meet the requirements for normality and homogeneity of variance, all data were ln (x + 1)-transformed.

Redundancy analysis (RDA) using CANOCO software for Windows 4.5 was chosen to determine the relative contributions of the measured environmental variables to the communities composition of the soil fauna. To reduce the number of variables, an abundance of 21 orders (sub-orders) of soil fauna, were used to perform the detrended correspondence analysis (DCA) and RDA, which included Prostigmata, Oribatida, Gamasida, Collembola, Coleoptera, Diptera, Homoptera, Hemiptera, Thysanoptera, Araneae, Isopoda, Hymenoptera, Orthoptera, Corrodentia, Symphyla, Plesiopora, Geophilomorpha, Dermaptera, Gastropoda, Lepidoptera, and Opiliones. The data were first analysed by DCA, suggesting that RDA is an appropriate approach (length of gradient < 3). To meet the requirements of DCA and RDA analysis, the data of soil fauna were ln (x + 1) −transformed, and the environment factors were square-root transformed.

3. Results

3.1. Soil fauna communities composition

We collected 19,684 individual samples belonging to 3 phyla, 7 classes, 21 orders (suborders) and 108 groups in the five salinization habitats, during six sampling periods. The mean density of soil fauna was 5876.5 individuals/m^2, ranging from 4194.5 individuals/m^2 in the Alkali spot habitat to 7157.22 individuals/m^2 in the *Artemisia*