Influence of Environment of Forest-Steppe Ecotone on Soil Arthropods Community in Northern Hebei, China

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Abstract

It was investigated on Soil arthropod communities in the forest-steppe ecotone in northern Hebei province to provide basic information on environment changes, which could promote the development of soil arthropod communities and be useful for the biodiversity conservation in the ecotone. From the preliminary identification, a total of 7994 individual soil arthropods were collected, which belonged to 25 groups, 6 classes and 24 orders. *Acarina*, *Hymenoptera* and *Collembola* were the dominant groups in the ecotone. The increased abundance of rare groups in the Forest zone with the richer vegetation, higher arthropod abundance and more substantial litter depth, could be interpreted as a reaction to the suitable soil environment and food supply. And these rare groups were sensitive to environmental changes, which could be regarded as biotic indicators for evaluating soil quality. The analysis of community diversity showed that every index was decreased from Forest zone to Forest-steppe zone and then to Meadow-steppe zone. These results indicated that the ecotone zone has abundant species, complicated community structure and shows the typical characteristics of the ecotone.

Keywords: Soil arthropods; Diversity; Ecotone; Community

I. Introduction

The ecotone is defined as the “zone of transition between adjacent ecological systems, having a set of characteristics uniquely defined by spatial and temporal scales and by the strength of the interactions between adjacent ecological systems[1]”. It is a vital area of transition in terrestrial ecosystems and is believed to be particularly sensitive to global climatic changes[2]. This area has more biological diversity, is more sensitive to global climate changes and has edge effects[3-5]. Therefore, ecotones are regarded as
a core indicator for early ecological warnings, management and practices[4]. The forest-steppe ecotone is located in the transition area between the forest zone and the meadow zone.

As a vital part of terrestrial ecosystems, soil fauna play an important role in the ecological balance, and their community composition and function also play an indispensable role in matter recycling, energy conversion, and soil structure formation and improvement. In recent years, many studies have been reported on the structure, diversity, stabilization and function of soil fauna communities. However, these studies mostly concentrated on single ecosystems, e.g., forest, grassland, farmland, etc.[6-8], revealed compositions, population dynamics, distribution characteristics and influential factors of soil fauna communities, and showed that the diversity of some soil fauna communities could indicate the presence of environmental changes caused by humans in terrestrial ecosystems, including wetland[9], forest[8], farmland[7] and polar region[11] ecosystem. Therefore soil fauna, which were regarded as soil ecological indicators, have been greatly developed. Wasile[12] found that earthworm diversity could indicate soil environment pollution. In recent years, researchers have discovered that the shape of the ecotone influences the propagation of the organism[13]. Chinese scientists have already analyzed vegetation categories, types, distribution rules and vegetation productivity in this field[14-16]. However, very little work has been done with respect to soil arthropods, which are important components of the terrestrial ecosystem and have some functional effects on the ecosystem. Because of the influence of the Pacific seasonal wind, the Chinese Forest-steppe ecotone is more distinct and diverse than those of other areas of Eurasia[17], and has one of the most active and noticeable biological communities. Exploring the structural characteristics and diversity of soil arthropods communities will not only enrich research contents theoretically but also further clarify the formation mechanisms and succession of communities. The aim of this paper mainly studied the structure and composition of soil arthropod communities, the main impact factors to the community, and investigated the status of soil arthropods in the ecosystem of the ecotone. We discussed the structure, ecological process of the soil arthropod community in order to supply some important theoretical information for ecological balance, to inspire the protection of biodiversity, and to promote further studies on the ecological function of soil arthropods in the Forest-steppe ecotone.

1 Material and methods

1.1 Study sites. The study area, SaiHaiBa in the northern part of Hebei province, is located in the eastern Inner Mongolia Plateau HunShanDaKe Desert (42°02’~ 42°36’ N, 116°51’~117°39’ E). It includes two areas: the upper area situated in Daxing’ anling Mountain, which belongs to the southern edge of the Inner Mongolia Plateau, with an altitude range of 1500~1939.6 m and a soil composition based mostly on sandy soil; and the lower area connecting the Yinshan and Daxing’anling Mountains, with an altitude of 1010~1500 m and a soil composition based mostly on forest soil and brown soil. The area has a typical semi-humid and semi-arid climate, with an average annual precipitation of 437.8 mm, an average annual sunshine of 2367.8 h, a snow-cover of 7 months, and an average annual temperature of -1.4 °C with temperature extremes of -42.8°C and 30.9°C for the lowest and highest values, respectively. There are abundant biological resources, with the forest coverage at 66.7%, and mostly cold, temperate coniferous forests and broad-leaved forests. Larch, spruce, Pinus tabuliformis, Betula platyphylla and Populus davidiana are the main woody plant populations. We divided this area into 3 zones, namely the Forest zone (A), Forest-steppe zone (B) and Meadow-steppe zone (C). Based on vegetation types we selected typical plots on the transect or near the transect. To the best of our abilities, we drew the transect through as many ecosystems as possible in the 3 zones. These 3 zones mainly include the following forest types:
Larix principis-rupprechtii (A1, B1, C1), Pinus sylvestris var. mongolica (A2, B2, C2), and natural secondary forest (A3, B3, C3).

1.2 Sampling method. From May to September 2006, we examined soil arthropods communities in every plot. Sampling was conducted once per month (except June). At each plot, we used a diagonal method to choose five points for soil sample collection. At each point we cleared away vegetation over the ground and then dug to a depth of 15 cm to get a soil monolith. Soil monoliths were divided into three layers (0-5, 5-10 and 10-15 cm), with a sampling area of 25×25 cm² for each layer. The soil in each layer was then sampled by a self-regulating geotome with a volume of 100 cm³ for mesofauna samples. The macrofauna was immediately sorted by hand from each soil layer and put into a bottle with alcohol (75%). Upon returning to the laboratory, the collected samples were separated using the Tullgren funnels method under the light from 60 W filament lamps for 48 h, and were identified and counted under a binocular dissecting microscope[18,19].

1.3 Data analysis. The number of individuals and biodiversity indices at different habitats were compared by a one-way ANOVA. Post hoc comparisons of means were done using the Duncan test at \( \alpha = 0.05, \alpha = 0.01 \).

The Shannon-Wiener diversity index is defined as:

\[
H' = -\sum_i P_i \ln P_i
\]  
where \( S \) is the total number of species, \( P_i \) is the abundance rate of the number of \( i \) species.

The Margalef abundance index is defined as:  
\[
d = (S - 1) / \ln N
\]  
where \( S \) is the number of groups, \( N \) is the total number of individuals.

For the Pielou evenness quantity:
\[
J = H' / \ln S
\]
where \( S \) is the number of groups.

The density-group index is given by:
\[
DG = \sum (D_i / D_{imax}) \cdot (D / GT)
\]
where \( D_i \) is the density of the number of \( i \) group; \( D_{imax} \) is the largest density of the number \( i \) group in each community, \( D \) is the number of groups and \( GT \) is the total number of groups in each community.

2 Results

2.1 Structure of soil arthropod community. A total of 7994 soil arthropods were collected from the 3 zones, falling into 25 groups, 6 classes and 24 orders. The dominant groups were Acarina, Collembola and Hymenoptera, accounting for 76.29% of the total individuals. Homoptera, Psocoptera, Coleoptera, Diptera, Lithobiomorpha and Araneae were the common groups, accounting for 20.43%, while others were rare groups. Hence the dominant and common groups were the main components of the soil arthropod communities in the ecotone of the Forest-steppe. The Forest zone had the most groups and individuals, but there was no significant difference among the three zones \((p>0.05)\). In this study area, rare groups possessed many species but had few individuals. And these rare groups had a weak ecological adaptability as they only existed in special environments. They could be regarded as ecological indicators of soil environmental change.

2.2 Diversity of soil arthropod community. The analysis of variance and multiple comparisons showed that Shannon-Wiener index \((H')\) of soil arthropod community in the three zones all reached a significant difference \((p<0.01)\) (Table 1). The abundance index \((d)\) and density-group index \((DG)\) also showed that the Forest zone was significantly higher than the Forest-steppe zone \((p<0.01, p<0.05)\). However, the evenness index \((J)\) only reached a significant difference between the Forest and Meadow-steppe zones \((p<0.05)\) while there was no significant difference in the density-group index \((DG)\) for the Forest-meadow and Meadow-steppe zones \((p>0.05)\). These results all indicated that changes to the
environmental gradient would result in significant changes for every diversity index of the soil arthropod community, with a tendency that decreased from Forest zone to Forest-steppe zone and then to Meadow-steppe zone.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Abundance (J)</th>
<th>Diversity (H')</th>
<th>Evenness (J)</th>
<th>DG index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest zone</td>
<td>11.52^A</td>
<td>3.61^A</td>
<td>0.61^A</td>
<td>12.78^A</td>
</tr>
<tr>
<td>Forest-meadow zone</td>
<td>7.88^Bb</td>
<td>2.84^B</td>
<td>0.48^B</td>
<td>8.36^B</td>
</tr>
<tr>
<td>Meadow-steppe zone</td>
<td>7.06^Bb</td>
<td>2.47^C</td>
<td>0.42^Bc</td>
<td>8.21^B</td>
</tr>
</tbody>
</table>

**Table 1** Biodiversity indices of soil arthropod in the ecotone

Means with the capital letters in the same column are most significantly different (p<0.01, n=3, Duncan's post hoc test); the small letters mean significantly different (p<0.05, n=3, Duncan's post hoc test).

In the Forest zone, A3 had the highest J index, d index, H' index and DG index, with the H' index and DG index being significantly higher than those of A1 and A2 (p<0.01) (Table 2). In the Forest-steppe zone, the J index, d index and H' index were the highest in B1 and lowest in B2 while the DG index was the highest in B3. Except for the J indices in B2 and B3, which had no significant differences (p>0.05), the other indices all reached significantly differences with each other (p<0.01). In the Meadow-steppe zone, the indices all had significant differences with one another (p<0.01), where the J index, d index and H' index were all highest in C1 while the DG index was the highest in C2.

**Table 2** Biodiversity indices of soil arthropod in different habitats

<table>
<thead>
<tr>
<th>Index</th>
<th>Forest zone</th>
<th>Forest-meadow zone</th>
<th>Meadow-steppe zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A1</td>
<td>A2, A3</td>
<td>C1, C2, C3</td>
</tr>
<tr>
<td>J</td>
<td>0.63^A</td>
<td>0.53_a</td>
<td>0.72^A</td>
</tr>
<tr>
<td>d</td>
<td>7.99^B</td>
<td>5.16_b</td>
<td>6.23^A</td>
</tr>
<tr>
<td>H'</td>
<td>3.30^C</td>
<td>2.57_B</td>
<td>3.50^A</td>
</tr>
<tr>
<td>DG</td>
<td>8.43^A</td>
<td>5.44_B</td>
<td>9.73^A</td>
</tr>
</tbody>
</table>

Larix principis-rupprechtii (A1, B1, C1), Pinus sylvestris var. (A2, B2, C2), natural secondary forest (A3, B3, C3).

3. Discussion and Conclusion.

Under a typical temperate continental monsoon climate, the groups of soil arthropod communities in this research region were more abundant than those in the subtropical climate regions[18]. Theoretically, soil fauna in the subtropical region, including species, individuals or structures, appeared to be more abundant than those in the temperate region. But in this area, the case was just the opposite. The Forest-steppe ecotone is located in particular environment which is the transitional area between the Forest and Steppe zones and has a more abundant biodiversity, a higher ecological fragility and more complicated and productive biotic communities than other areas. Those characteristics probably stimulate the ecotone to have an abundant and changeable composition in regards to soil arthropod communities. This area had distinct differences compared to the other areas that were located in the same temperature zone. These results indicated that the composition of the soil arthropod community for the research area was greatly different from that of other areas in the same temperature zones, and the different natural environments and niches of soil fauna community may be interpreted these differences.
Rare groups are composed of soil fauna that are sensitive to environmental changes and exist in specific habitats. In this investigation, the Forest zone had the highest number of rare groups and its vegetation cover, soil porosity and litter depth were the best of the three zones. Thereby, these rare groups were regarded as bio-indicators that could be used to evaluate the quality of the soil. Because of the low density, Dermaptera and Pseudoscorpiones only existed in the Forest zone, while Isoptera appeared only in the Forest-steppe zone, and Orthoptera was discovered only in the Meadow-steppe zone. This most likely shows that their living environment has specificity.

The number of soil arthropod species in this studied ecotone was 20-25, which was higher than that of the similar ecosystems even though the total number of individuals was lower. Therefore, the composition of the soil arthropod community was diverse and showed the typical characteristics of the ecotone. For every change in the environmental gradient, every diversity index for the soil arthropod community also showed significant changes, with a tendency that decreased from Forest zone to Forest-steppe zone and then to Meadow-steppe zone. The Forest zone had the most abundant number of species, the best distribution and the highest diversity, with the Forest-steppe zone taking second place, and the Meadow-steppe zone with the lowest values for all three criteria. These indicated that the Forest-steppe ecotone had typical environment with different composition of soil arthropod community. We expect the soil arthropod data measured in this study to be useful for the environmental protection and biodiversity conservation in ecotone zone.
References


