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Effects of land use changes on winter-active Collembola in Sanjiang Plain of China

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ABSTRACT

Sanjiang Plain is the largest concentrated area of freshwater wetlands in China, however nearly 80% of these freshwater wetlands were drained or reclaimed in the past 50 years. It is important to know whether wetlands reclamation would affect soil invertebrates, especially the winter-active invertebrates. During November 2011 to April 2012, we used pitfall traps and in-field direct observation methods to study the activity of collembolans in wetland, and a reclaimed forest plantation and soybean field. In total, 3465 collembolans were captured and identified to 8 species from 6 families. *Desoria* sp. 1, *Desoria* sp. 2 and *Desoria* sp. 3 were the three dominant species. Collembolan abundance and assemblages were significantly affected by the land use changes. The results showed that (1) Collembola captured by pitfall traps showed a highest abundance in wetland, with ~50% decreased abundance in soybean field, and ~75% decreased in the forest plantation. (2) Collembola activity changed during the winter season, their activity significantly increased from early winter to late winter; with a peak in March in all three land use types. (3) Collembola assemblages were affected by land use changes with a significant decrease of frequency of *Desoria* sp. 3 and a significant increase of frequency of *Desoria* sp. 2 in soybean field and forest plantation. (4) Collembolan densities on the snow surface usually peaked between 1400 h and 1500 h, and decreased quickly when the temperature dropped below freezing. Mean abundance reached 119 individuals m^{-2} on the snow surface in wetland, 152 individuals m^{-2} in soybean field, and 64 individuals m^{-2} in forest plantation. All collembolans moved up and down through the snow profile depending on temperature, no collembolans were found on the snow surface in the evening. Our study indicated that the reclamation of wetland resulted in a significant decrease of abundance and a different assemblage of winter active Collembola in Northeast China, but land use changes did not change their pattern of activity: Collembolans were rarely active in early and middle winter and mostly active in late winter. Their daily densities on the snow surface fluctuated according to both air temperatures and land use types.

1. Introduction

Land use change is one of the primary factors determining patterns of biodiversity of soil organisms, such as Collembola, at local and regional levels (Lavelle et al., 1997; Bengtsson, 2002). Moreover, landscape configuration (e.g., heterogeneity, fragmentation) and the type of land use (e.g., pasture, farm forest) also regulate Collembola community composition (Filser et al., 1996; Lauga-Reyrel and Deconchat, 1999; Alvarez et al., 2000; Dombos, 2001). For instance, Collembola communities react to change in management practices (Dekkers et al., 1994; Filser et al., 1995; Loranger et al., 1999; Frampton, 2000; Alvarez et al., 2001). Collembolan communities have also been shown to vary in abundance and species composition according to changes in vegetation and soil conditions (Hägvar, 1982; Ponge, 1993; Chagnon et al., 2000). A decrease of species richness and total abundance was observed toward more intensively managed land from natural forests to agricultural fields (Ponge et al., 2003, 2006; Sousa et al., 2000, 2004, 2006).

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Most of the studies discussed above had a focus on changes in Collembola communities during the growing season. However, some species are active in winter, and the responses of winter-active Collembola, which is a sub-set of the surface-dwelling species in an area, to land use changes have not previously been studied. They usually represent a group of species with patchy distribution that may be difficult to study quantitatively during summer, even though they can be among the most abundant species in a particular area (Leinaas, 1981a). In winter time, however, they are more dispersed, and easier to be studied on the snow surface. Invertebrates active in winter are affected by the snow cover. Ecologically, the snow layer creates three different microhabitats: subnivean (below snow), intranivean (within snow), and supranivean (the snow surface), each with its characteristic arthropod fauna (general summary by Aitchison, 2001). Collembola active in subnivean environments have been documented by using pitfall traps (Näsmark, 1964; Aitchinson, 1974, 1979; Schmidt and Lockwood, 1992; Hägvar and Hägvar, 2011), some of them may migrate up into the snow or to the snow surface to escape water logging or predation (Brummer-Korvenkontio and Brummer-Korvenkontio, 1980; Leinaas, 1981a, 1983). Supranivean activity of Collembola was studied by many authors (Fitch, 1850; Latzel, 1907a,b; MacNamara, 1919, 1924; Stürbing, 1958; Durbin, 1975; Leinaas, 1981a,b,c, 1983; Zettel, 1984, 1985; Janetschek, 1990; Hägvar, 1995, 2000). *Hypogastrura socialis* was the most abundant species on snow in forests in Norway. Leinaas (1981a) repeatedly measured a density on snow of approximately 4000 individuals m^{-2} during February and March, and Hägvar (1995) found that they were roughly 2000–10,000 m^{-2} on the snow surface during the middle of April 1995, and showed a directional mass migration on the snow surface. Several species of Collembola have been documented to perform directional migration on the snow, orienting by the sun or toward tall objects (Leinaas and Fjellberg, 1985; Hägvar, 2000). The migration ability on the snow surface in winter makes it possible for them to move over great distances, partly to establish new colonies and partly to exchange genes between colonies (cf. Leinaas, 1981c; Zettel, 1985). Land use changes may change their habitat preferences in harsh winter conditions.

Sanjiang Plain, located in the east of Heilongjiang province, northeastern China, is the largest concentrated area of freshwater wetlands in China. Due to large-scale agricultural development, nearly 80% of the freshwater wetlands in Sanjiang Plain have been extensively converted to agricultural fields in the past 50 years, and thus has been significantly degraded (Liu and Ma, 2002). While many efforts have been made to analyze climate changes, landscape changes, and effects of wetland reclamation on local environment in Sanjiang Plain (Zhang et al., 2001; Yan et al., 2001; Wang et al., 2006), there is still a lack of information on the local biodiversity of soil invertebrates and the effects of land use change on them (Wu et al., 2008; Bao et al., 2010; Sun and Wu, 2012). The snow cover in Sangjiang Plain may create various living habitats for winter-active collembolans, which deserve further studies.

Previous studies have shown that collembolan communities were affected by land use change during the plant growing season (Ponge et al., 2003, 2006; Sousa et al., 2004, 2006; Chang et al., 2013). However, no studies focused on whether and to what extent the winter activity of Collembola is affected by land use change. Pitfall traps and direct in-field observations methods were used to study the effects of land use on the abundance and community structure of collembolans in winter during the period of snow cover. Expected effects are indicated in the following three hypotheses: (1) Abundance and species dominance of winter active Collembola are affected by the different land use of the area. (2) Land use has no effect on Collembola activity in the subnivean space, within the snow pack and on the snow surface. (3) The Collembola activity in winter is affected by temperature and time. To our knowledge, this is the first report of winter-active Collembola in China, and the first study on the responses of winter-active collembolans to land use changes.

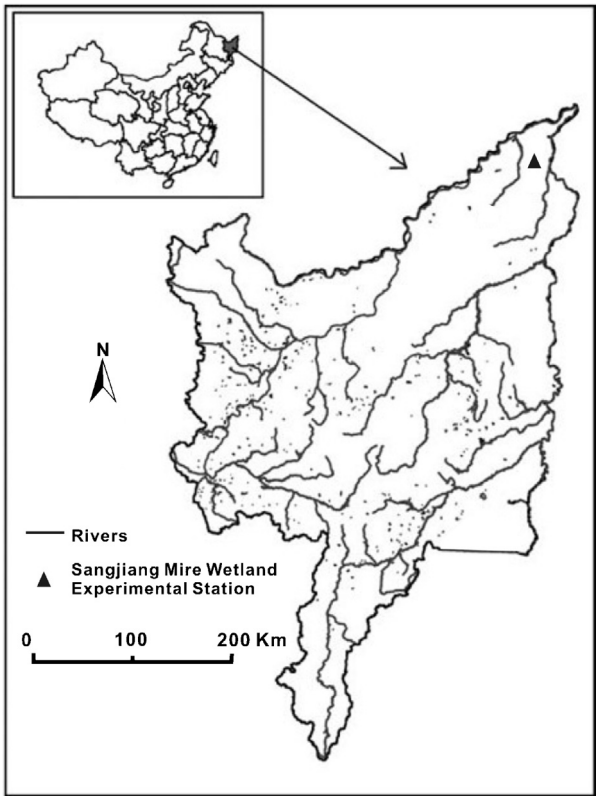

Fig. 1. Location of the Sanjiang Plain and the Sanjiang Mire Wetland Experimental Station.

2. Materials and methods

2.1. The study area

The study was carried out from November 2011 to April 2012, at the 35 years old long-term observation station-Sanjiang Mire Wetland Experimental Station (47°13′ N, 133°13′ E), Chinese Academy of Sciences, located in the center of the Sanjiang Plain. The site is situated in Heilongjiang Province of northeastern China; it is a low alluvial plain, which was formed by the Heilong, the Songhua and the Wusuli rivers. This region experiences a temperate humid to sub-humid continental monsoon climate. The position of the study site is shown in Fig. 1.

The mean annual temperature ranges from 1.4 to 4.3 °C, with average maximum of 21–22 °C in July and average minimum −21 to 18 °C in January. Daily maximum and minimum temperatures during the winter period are shown in Fig. 2 .The elevation of the study area is 55.4–57.9 m above sea level, and the mean annual precipitation is 565–600 mm. More than 60% of the annual precipitation falls between July and September. The freezing period is up to 7–8 months (from November to May), and the site is under continuous snow cover for a period of up to 6 months (from November to April). All three land use types are on lessive soil.

The study was performed in three adjacent areas of different land use: a wetland site (length × width = 100 m × 150 m), a reclaimed soybean field (length × width = 200 m × 200 m) and a reclaimed forest plantation (length × width = 100 m × 100 m), which separated the wetland and soybean field. The wetland was