Agriculture, Ecosystems and Environment 164 (2013) 145–154

Contents lists available at SciVerse ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Landscape and site effects on Collembola diversity and abundance in winter oilseed rape fields in eastern Austria

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ARTICLE INFO

Article history:
Received 24 May 2012
Received in revised form 6 September 2012
Accepted 24 September 2012

Keywords:
Brassica napus
Collembola
Epigeic and endogeic species
Dispersal
Landscape diversity
Species richness
Austria

ABSTRACT

Soil animals are rarely considered in landscape ecology although recent findings show that landscape composition and habitat fragmentation may exert a strong influence on their communities. We assessed the relationships between landscape parameters and the species richness of Collembola (springtails) in agricultural eastern Austria, hypothesizing that the richness of surface active (epigeic) species are more significantly correlated with landscape-scale parameters than soil living (endogeic) species. We used pitfall traps and soil samples to measure species richness and abundance of the two life forms in 29 oilseed rape fields in differently structured landscapes.

Epigeic species richness was positively correlated to landscape parameters like landscape diversity, habitat richness, isolation of open habitats and area of oilseed rape fields at small to medium (250–1000 m) and at larger (1000–1750 m) landscape scales around the investigated sites. Endogeic species richness was also significantly correlated with landscape parameters like landscape diversity and road-side strip length. Total species richness was significantly correlated with landscape diversity at a larger scale, isolation of open habitats and proportion of woody area at a smaller spatial scale. Landscape diversity measures explained a higher percentage of the diversity of epigeic (42%) than of endogeic diversity (32%). Epigeic abundance was not significantly correlated to any of the site parameters, but with landscape parameters like oilseed rape area, woody area and minimum distance to dry grassland. Endogeic abundance was only correlated to oilseed rape cover.

Our results suggest that parameters associated with landscape diversity can be good predictors of Collembola diversity at two spatial scales: At small scales probably due to active migration from bordering hedges, forests or grasslands; and at larger scales possibly due to passive wind dispersal. Soil ecologists rarely take landscape-scale variables into account, and our findings may contribute to broader recognition of the importance of landscape parameters in investigations of soil biota.

1. Introduction

Collembola species are classified as epigeic (surface active or epedaphic), hemiedaphic or euedaphic (together endogeic) according to their occurrence on the soil surface and litter layer (epigeic), the top 5 cm of the soil (hemiedaphic) and deeper soil layer (below 5 cm – euedaphic; see Gisin, 1943; Petersen, 2002). Epigeic species actively move on the soil surface, within the litter layer and climb on vegetation and are usually collected with pitfall traps. Active migration of epigeic Collembola was described by Alvarez et al. (1997, 2000), Frampton (2002), Frampton and van den Brink (2002), Frampton et al. (2007), Hågvar (1995, 2000) and Mebes and Filser (1997) and is probably taking place over shorter distances on the soil surface and between bordering habitats. Endogeic species are collected with soil samples and are found within the soil pores. Active migration of these species is limited to very short distances within the soil (10^{-2} and 10^{-1} m in a laboratory setup; Ojala and Huhta, 2001). Endogeic species are assumed to be influenced more by site parameters because they live within soil pores, they are smaller and less mobile.

Soil type, temperature, moisture, acidity, the presence or absence of a litter layer and the fungal community influence communities (Betsch, 1991; Betsch and Cancela da Fonseca, 1995; Hashimoto and Tamura, 1994; Klironomos and Kendrick, 1995; Kovác, 1994; Ponge et al., 1993). Site parameters that seem to have the most influence are soil acidity, vegetation type and humus form (Ponge and Prat, 1982; Ponge, 1993). However, it is not yet fully understood to what extent these parameters influence the structure and composition of Collembola communities at particular sites.

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0167-8809/$ – see front matter
http://dx.doi.org/10.1016/j.agee.2012.09.016

Landscape parameters could therefore also affect Collembola but have rarely been considered in soil ecology. The landscape diversity (or land-use diversity, see also Yoshida and Tanaka, 2005) around a site could be important as they may determine the animals' dispersal rates in the landscape matrix. In recent years, some studies have investigated the effects of the landscape on Collembola species and communities. Chust et al. (2000, 2003a,b) studied the effect of fragmentation in Pyrenean forests on soil Collembola communities and found a negative relationship between landscape heterogeneity and richness of the endemic species, indicating that landscape fragmentation is a potential threat to the endemic component of soil assemblages. Querner (2002) found positive correlations between the diversity of surface active Collembola and landscape diversity around 50 fragmented dry grassland remnants in eastern Austria. This indicates that neighboring grasslands in close vicinity to the sites are important and influence the number of remnant dependent species. The effects of land use intensity and landscape diversity on Collembola richness and communities were investigated by Ponge et al. (2003, 2006), Sousa et al. (2004, 2006) and Vanbergen et al. (2007). All these studies suggest landscape-scale effects on Collembola communities. Passive dispersal by wind was described for Collembola by Glick (1939), Freeman (1952), Gressitt et al. (1961) and Johnson (1957). Epigeic species are assumed to be transported more frequently by wind across the landscape then the soil living species, as they seldom come to the soil surface or climb on the vegetation. See also Ettema and Wardle (2002) for small scale and large scale effects on soil fauna communities.

But at which spatial scales (200 or 2000 m) are Collembola affected by the landscape and due epigeic and endogeic species respond similarly to the landscape diversity?

To answer these questions, we sampled epi- and endogeic Collembola communities in 29 winter oilseed rape fields (OSR) situated within differently structured landscapes, ranging from divers landscapes to simple ones. We hypothesized: (1) That epigeic species are significantly correlated to landscape parameters because they are larger, more mobile and live on the soil surface. Active movement and passive dispersal from one landscape structure (or patch) to another seems more likely and a more divers landscape should results in a higher species richness at each site. (2) Endogeic species in contrast are more significantly correlated to site parameters because they live within the soil pores, are smaller and therefore less mobile. (3) OSR fields in more diverse landscapes comprised of smaller fields, grasslands, fallows, forests and hedges, contain a higher Collembola diversity, than OSR fields in structurally simple landscapes with large fields and fewer natural habitats because species are constantly introduced actively and passively in the OSR field. The aim of this paper is to try to answer their questions and detect effects at landscape scale on Collembola. We are not investigating the long term establishment of each species and assume that there is a natural dynamic of new and already occurring species migration or being constantly dispersed and introduced between different landscape structures. Some of these species establish themselves, other get extinct after some time.

2. Methods

2.1. Site description

This study was conducted in an agricultural region of 240 km^2 size approximately 40 km east of Vienna, Austria (central coordinates: 16°57′E, 48°04′N). The main soil type of the region is chernozem with a pannonian (continental) climate. Within this region, 29 winter oilseed rape fields were selected, embedded in differently structured landscapes ranging from structurally simple (low landscape diversity, mainly agricultural fields) to structurally complex (high landscape diversity with numerous patches of fallow, grassland and forest, hedges and road-verge strips; details in Zaller et al., 2008a). Oilseed rape was sown in August and September 2004 and the fields were fertilized and treated with herbicides, fungicides and insecticides following common agricultural practice. In January 2005, an area of 1 ha within each field was excluded from pesticide applications and this area was used for sampling surface active and soil living Collembola. The study was part of a larger project on the landscape ecology of oilseed rape pests and pest predators (Drapela et al., 2008; Zaller et al., 2008a,b, 2009).

2.2. Collembola sampling

From 13th to 27th of April 2005, six pitfall traps of 1.7 cm diameter were used to collect surface active Collembola at each site. Traps were placed along a 50 m transect with a spacing of 10 m between traps and filled with ethylene glycol and a drop of odorless detergent. After an exposure of 14 days, the traps were removed and the Collembola determined to species level and counted.

Just prior to pitfall-trapping (15th, 16th, 23th April 2012), 20 soil samples were taken in each field along two parallel transects (each 50 m long and 10 m apart) with a spacing of 5 m between samples. 57 mm × 57 mm steel tubes (Bruckner, 1998) were inserted to a depth of 100 mm and the soil was stored in plastic bags and cooled (10 °C) until extraction. Soil samples were extracted the same day or stored until extraction for maximum of 1 week at 10 °C.

All soil samples were extracted in a Berlese–Tullgren device with 33 extraction units and placed into 10% benzoic acid solution for 7 days. In order to reduce data variability, the 20 soil extracts from of each field were pooled in a container, evenly mixed by hand, and five subsamples taken from which the Collembola were identified and counted (see Bruckner et al., 2000; Querner and Bruckner, 2010 for a detailed description of the pooling and subsampling). The pitfall catches were not pooled and subsampled, as, according to our experience, they mostly yield much less variable abundance and species richness data than soil cores.

2.3. Collembola data

Collembola were identified using the keys of Gisin (1960), Stach (1960, 1963), Babenko et al. (1994), Zimdars and Dunger (1994), Pomorski (1998), Bretfeld (1999), Potapov (2001) and Thibaud et al. (2004). Each species was classified as “epigeic” or “endogeic”, according to its frequency in the sampling methods: Species collected in higher frequency in the pitfall traps than in the soil samples were classified as epigeic, and vice versa for endogeic species. If a species was found by both methods equally frequently, the species was retained in both lists for further analysis (see Querner and Bruckner, 2010). Gisin (1943) and Petersen (2002) divided Collembola species in three groups according to their morphological characteristics. The three groups also differ in vertical stratification: Epigeic, hemiedaphic and euedaphic. We did not separate hemiedaphic and euedaphic species in this investigation as we assume that that these two groups respond similar to the site parameters and our main research question were the comparison with the epigeic species and landscape parameters.

As dependent parameters we used the number of species from the pitfall traps (surface species richness), from the soil samples (soil species richness), the pooled species richness from both sampling methods (total species richness), and the abundance (number of specimens) from the pitfall traps (surface abundance) and soil