



Spider assemblage structure and functional diversity patterns of natural forest steppes and exotic forest plantations

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ABSTRACT

The majority of natural forest steppes in Central-Europe were converted to forest plantations, a significant part of plantations are composed of exotic pine trees. This brings dramatic changes in habitat structure. The formerly open-canopy forest patches and grasslands became closed-canopy forests and key habitat factors were altered, such as microhabitat diversity, plant species composition, microclimate, and amount of dead organic matter. Here we studied the difference in spider species richness, assemblage composition, and functional diversity of native forest steppes, exotic pine plantations, their edges, and adjacent grasslands. We selected 10 native forest patches and 10 pine plantations in commercial maturity, all plantations had direct interface with extensive forest steppe areas. We sampled spiders in forests, forest edges, and adjacent steppe grasslands, resulting in 60 sampling plots. We found different species composition in natural forest patches and pine plantations; however forest edges and grasslands near forest edges did not differ significantly. Spiders with preferences for shaded and humid habitats were associated with forests. Web builders were associated with pine plantations and their edges, large vegetation dwelling spiders had preferences for grasslands and native forest edge, and ballooning spiders were associated with grasslands and edges. Pine forest belts around natural forest steppe patches, besides being low quality secondary habitats for forest steppe spiders, also hamper effective dispersal; the high density of trees and the lower wind speed may act as barriers for effective ballooning. Contrary to our expectations, we found lower functional diversity at natural sites than at pine plantations. The hot and dry microclimate of natural forest steppes favours some trait states (e.g., drought-tolerant, preferences for open habitats), and this may lead to convergence in trait values and a lower functional diversity of forest steppe spider assemblages than the that of assemblages in pine plantations.

1. Introduction

Land-use change and intensification are among the main drivers of ecological change and biodiversity loss in terrestrial ecosystems (Phalan et al., 2011). A major pressure on biodiversity is the destruction of forest habitats and their conversion into plantation forests of exotic tree species (Paillet et al., 2010). In Central Europe, ~75% of the forests are primarily under intensive management, focusing almost entirely on wood production (Magura et al., 2015). Plantation forests are typically composed of just one or a few tree species, and the tree density is higher than in natural forests. Furthermore, plantations usually have a lower resilience to environmental change than diverse natural forests (Brocknerhoff et al., 2013). Increased stand density may decrease their resistance to drought by increasing competition for water (Giuggiola et al., 2013). A closed canopy also decreases light availability for lower vegetation strata, leading to lower understorey biomass (Balandier

et al., 2006). The forest floor microclimate of pine plantations is moist and sheltered compared to native forests (Humphrey et al., 2004). This can in turn alter key habitat factors such as microhabitat diversity, plant species composition, and amount of dead organic matter (Henneron et al., 2015). Furthermore, plantation forests are generally prone to invasion of generalist and exotic herbaceous plant and invertebrate species (Magoba and Samways, 2012; Gallé et al., 2015; Hogg and Daane, 2015). Pine plantations support low invertebrate diversity compared to natural forests (Finch, 2005; Brocknerhoff et al., 2008; Nagy et al., 2015). However they may provide suitable habitat for native species, with species richness similar in pine plantations and native forests (Quine and Humphrey, 2010). They are likely to be less capable of providing ecosystem services that are linked to biodiversity (e.g., pest control). However, increased overall functional diversity in plantations may enhance resistance and resilience of such ecosystems (Ares et al., 2010).

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The conservation value of plantation dominated landscapes depends on the ability of forest plantations to act as secondary habitats and the ability of remaining natural habitat patches to act as refuges for forest-adapted species (Pawson et al., 2008; Skłodowski, 2014). Natural patches are source habitats of the native biota, thus landscape structure may be a critical determinant of biodiversity within forest plantations (Barbaro, et al. 2005).

The forest steppe zone is a transition between closed forest regions and steppes running from the Pannonian ecoregion (Central Europe, including Hungary) through Asia (Magyari et al., 2010). Forest steppes of the region are characterised by dry, sandy grasslands and forest patches with relatively open canopies and diameters of 10–100 m (Erdős et al., 2014). Significant forest steppe areas in Hungary were converted to commercial plantation forests of native (poplar) and exotic (black locust and pine) tree species (Biró et al., 2008, 2013). This brought dramatic changes in forest steppes; the formerly open-canopy forest patches and grasslands became closed-canopy forests (Erdős et al., 2015a).

The majority of forest ecological studies of invertebrates are focusing on species diversity patterns (Kuuluvainen et al., 2012), that consider the impact of forest attributes on species richness and distribution patterns (e.g. Jordán et al., 2007, Gallé et al., 2016), while the impact of forest attributes on functional and phylogenetic diversity of invertebrate assemblages remains relatively rarely considered (Magura, 2017). However, according to recent studies, invertebrate functional diversity may be affected by forest type and structure (Gallé et al., 2017). Functional diversity of invertebrates in native forest with high structural heterogeneity of the forest floor is higher than exotic plantations with simple habitat structure due to occurrence of functionally unique, rare species (Bihn et al., 2010, Corcuera et al., 2015). However, according to our knowledge no study has yet addressed the functional diversity of invertebrates in forest steppes and pine plantations.

The aim of the present study was to examine differences in species richness, assemblage composition and functional diversity of native forest steppes, exotic pine plantations and both natural forest and pine plantation edges. More specifically, we examined the following hypotheses using ground-dwelling spider data collected at replicate sites: (1) plantations have a negative effect on spider species richness of forest edges and nearby grasslands; and (2) habitat-structure-induced species trait selection shapes the species composition and functional diversity of plantations.

2. Materials and methods

2.1. Study region and sampling design

The study was carried out in South-Hungary where the natural vegetation is forest steppe, and the majority of natural forest steppe areas are concentrated in the Carpathian basin. In forest steppes, poplar (*Populus alba*) and hawthorn (*Crataegus monogyna*) patches are embedded in extensive dry grasslands resulting in a structurally and microclimatically complex ecosystem (Erdős et al., 2014). We selected 10 sampling sites in two extensive dry forest steppe areas near the villages of Pirtó (n = 5) and Tázlár (n = 5) in the Kiskunság region of Hungary.

Altogether, 10 short-rotation plantations of exotic scots pine (*Pinus sylvestris*) at commercial maturity were also selected for this study. All plantations had direct interface with extensive forest steppe areas, with five sites situated near Pirtó and five sites near Tázlár. Forest steppe sites were situated at least 500 m from the edge of the natural area. At each of the 20 sites, forests, edges, and grasslands were sampled, resulting in a total of 60 sampling plots.

2.2. Study site and sampling

We used plastic pitfall traps of 8.5 cm diameter to sample the ground-dwelling spider fauna. Three traps were installed at each plot and placed 8 m apart in a line. Traps in pine forest and grassland plots were placed 20 m from the habitat edge, and those of the natural forest patches were placed in the centre of the forest patch. Edge plot traps were placed one meter towards the grassland from the line of the last tree trunks. Traps were filled up to one third with 50% ethylene glycol and water solution to preserve the samples. A plastic roof was placed above each trap to prevent dilution of the preservative through precipitation, and traps were equipped with a plastic funnel to reduce the chance of escaping. Trapping was conducted from 2 to 14 April and from 6 to 20th June in 2015. Invertebrates collected in the traps were stored in 70% ethanol, and adult individuals were identified to species level. For further analyses, the species data from traps were pooled according to sampling sites and periods, resulting in 60 statistical samples.

2.3. Data analysis

The multivariate difference in spider assemblage structure between habitat types was analysed with nonmetric multidimensional scaling (NMDS) using the vegan package (Oksanen et al., 2015) in R environment (R Core Team, 2015), based on the Bray-Curtis distance measure, and a maximum number of 25 random starts were used to search for a stable solution. The data were submitted to a Hellinger transformation prior to the ordination (Legendre and Gallagher, 2001). Analysis of similarities (ANOSIM), based on Bray-Curtis dissimilarity matrices with 5000 permutations, was performed to test for differences among spider assemblages in pine plantations and natural forests, in plantation edges and natural forest edges, and in grasslands near pine plantations and near natural forests, respectively. If the ANOSIM detected significant differences between assemblages of the above pairs of habitat types, we applied the indicator value analysis (IndVal) to identify characteristic spider species (Dufrene and Legendre, 1997). We calculated the IndVal value on the basis of the relative frequency and relative average abundance of the species in the samples. The statistical significance of the species indicator values was evaluated by a Monte Carlo procedure.

For the functional diversity approach, six functional traits were chosen. Species were classified on the basis of stratum, hunting strategy, dispersal (two categories). Species preferences for humidity and light were classified into five and four categories, respectively. If a species was assigned to more than one category, the values were averaged. Spiders were considered as humidity or light generalists, and their score was excluded from further analyses if they were assigned to

Table 1
Description of spider traits.

Functional trait	Description
Stratum	Ground-dwellers, vegetation dwellers and species occurring on both the ground and vegetation Buchar and Ruzicka (2002)
Hunting	Active hunters and web-builders Cardoso et al. (2011)
Ballooning	Species known to balloon (species included in lists of ballooning spiders), spiders likely to balloon (genus included in lists), spiders not likely to balloon (not included in lists), according to Bell et al. (2005) and Blandenier (2009)
Humidity preferences	Scores, 1: very dry, 2: dry, 3: semi-humid, 4: humid, 5: very humid Buchar and Ruzicka (2002)
Light preferences	Scores, 1: open, 2: semi open, 3:partly shaded, 4: shaded Buchar and Ruzicka (2002)
Size	Continuous in mm Nentwig et al. (2017)

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