Ecological Indicators 80 (2017) 344–353

Contents lists available at ScienceDirect

Ecological Indicators

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

Research paper

Spatial distribution of insect indicator taxa as a basis for peat bog conservation planning

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ARTICLE INFO

Keywords:
Peatlands tyrphophilous
Environmental indicators
Succession
Carabidae
Formicidae

ABSTRACT

Peat bogs are highly endangered ecosystems worldwide. In the Western Balkans, they represent fragmented habitat patches, where insect diversity and implications for the habitat loss are poorly known. Carabid beetles and ants, widely used environmental indicators, were sampled by pitfall trapping in the largest and oldest Croatian peat bog and at its edges. We found that tyrphobiontic—bog specialist—species were absent in both taxonomic groups, which is likely due to biogeographical limitation for dispersal of these species into this region. With this study, tyrphophilous—typical of bogs—species have been recognised as environmental indicators in the Western Balkans peat bogs. Assemblages of both taxa were strongly affected by specific conditions in the peat bog – high soil moisture and *Sphagnum* moss dominance, showing that edges are more favourable habitats for both taxa. Overall, carabid beetle activity density was significantly higher at the edge than at the peat bog, while species richness increased for both taxa at the edge, but not significantly. Spatial distribution of tyrphophilous species differed between studied taxa, with ants being more abundant in the peat bog, and carabid beetles at the edge. Additionally, some stenotopic and globally endangered species preferred edges. Occurrence of tyrphophilous and globally endangered species highlights the great conservation value of peat bog habitats in the Western Balkans. However, successional changes in vegetation are changing hydrological conditions of the peat bog. Here we suggest active conservation measures to preserve these unique soil invertebrate zoocoenoses.

1. Introduction

Peat bogs are a unique type of wetland characterised by specific environmental conditions, such as high acidity and soil moisture, extremely low nutrient availability and low oxygen levels (Rydin and Jeglum, 2006; Spitzer and Danks, 2006). The species that inhabit peat bogs are often highly specialised and mostly confined to them (Spitzer and Danks, 2006). These species can be classified into four categories: (a) tyrphobiontic — occur exclusively in bogs, (b) tyrphophilous — typical of bogs, but not strictly confined to them, (c) tyrphoneutral — distributed across different types of habitats, and (d) tyrphoxenous — immigrants that cannot survive in bogs (Peus, 1928; Roubal, 1934). Peat bog specialists are found among both terrestrial and aquatic invertebrate taxa *e.g.*, butterflies (Spitzer et al., 1999), ants (Vepsäläinen et al., 2000), carabid beetles (Mossakowski et al., 2003) and chironomids (Rydin and Jeglum, 2006).

In the Western Balkans, peat bogs are scarce, small in area and highly fragmented (Topić and Stančić, 2006). They were formed during or directly after the last glaciation period, when climatic conditions were similar to cold boreal climates (Horvat, 1950). These habitats are today critically endangered mainly due to the abandonment of traditional land management practices, climate change, and changes in drainage regimes, resulting in rapid vegetation succession (Hršak, 1996; Topić and Stančić, 2006). Woody and grassy vegetation are overgrowing peat bogs, shading *Sphagnum* spp. L. mosses, drying the soil and causing changes both in vegetation composition and structure. Furthermore, within the last 50 years the areas of some Croatian peat bogs have drastically decreased and several bogs have completely or partially disappeared (*e.g.* Dubravica and Vukmanić bog, Hršak, 1996; Topić and Stančić, 2006). Nevertheless, these glacial refuges are centres of plant and invertebrate diversity in the Western Balkans, containing many rare and endangered species (Alegro and Šegota, 2008; Brigić et al., 2014; Previšić et al., 2013).

Lack of any management practices will result in further habitat reduction, and invariably cause a loss of specialised and rare peatland biota (Brigić et al., 2014; Topić and Stančić, 2006). Since peat bogs of

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http://dx.doi.org/10.1016/j.ecolind.2017.05.007
Received 4 July 2016; Received in revised form 14 April 2017; Accepted 2 May 2017
Available online 24 May 2017
1470-160X/

this region have been underexplored, we currently cannot predict the impact their loss will have on biodiversity. To examine the specialization of fauna at peat bogs in Western Balkans we chose carabid beetles and ants, two taxa previously used as environmental indicators of changes in peat bog habitats (Främbs et al., 2002; Vepsäläinen et al., 2000). Moreover, population densities of tyrphobiontic and tyrphophilous carabid beetles often reflect quality of habitats in north European peatlands (Aleksandrowicz, 2002; Buchholz et al., 2009; Mossakowski et al., 2003). Carabid beetles and ants are highly sensitive to changes in environmental factors, such as soil moisture (Maes et al., 2003; Thiele, 1977), vegetation structure (Gallé et al., 1998; Taboada et al., 2008; Pizzolotto et al., 2014) and temperature (Lessard et al., 2009; Thiele, 1977), and as such quickly respond to changes in habitat.

The objectives of our study were to (1) determine the occurrence of tyrphobiontic and tyrphophilous carabid beetles and ants in the Western Balkans peat bog; (2) compare carabid beetle and ant assemblages from two main habitat types: peat bog and the edge; (3) examine the effect of vegetation and environmental variables (soil moisture, soil temperature, soil pH) on the spatial distribution of carabid beetle and ant assemblages; and (4) provide guidelines for future conservation management planning.

2. Material and methods

2.1. Study area

Đon močvar peat bog is situated in central Croatia, near Blatuša village (N45°, E15°, 130 m a.s.l). It covers an area of 10 ha, and represents the oldest and largest peat bog in Croatia (Alegro and Šegota, 2008). This region is characterised by a temperate humid climate with an average annual temperature of 10.5 °C and an average annual precipitation of 1,050 mm (Zaninović et al., 2008). The peat bog's area has decreased from 40 ha to 10 ha since the beginning of the 20th century. This reduction was caused by drainage and abandonment of traditional grazing and mowing practices. Consequently, the spread of woody and grass vegetation dominated by *Alnus glutinosa*, *Betula pendula*, *Frangula alnus*, *Molinia caerulea* and *Phragmites australis* has changed the vegetation composition and structure of the peat bog (Alegro and Šegota, 2008). The peat bog and adjacent area are currently protected as a Botanical Reserve and included in the NATURA 2000 network.

Đon močvar peat bog is a complex ecosystem, composed of a variety of microhabitats such as open woodless *Sphagnum* spp. sites, deep hollows and small ponds. Most of the vegetation consists of a *Drosero-Caricetum echinatae* association (Table 1), and the moss layer is dominated by *Sphagnum* species. The peat bog edge is mainly overgrown with flooded forest of a *Frangulo-Alnetum glutinosae* association (Table 1). These edges are a source of woody vegetation which spreads into the peat bog. The forests surrounding the slopes around the peat bog consist of an *Epimedio-Carpinetum betuli* association.

2.2. Soil arthropod sampling and identification

Soil arthropods were sampled using pitfall traps at two focal habitats – peat bog and peat bog edge. These two habitats were selected due to suitable microclimatic conditions (particularly high soil moisture) that could support typical soil arthropod peat bog assemblages. Upland forest (*Epimedio-Carpinetum betuli* association) was characterised by low soil moisture (below 30% during two vegetation seasons), as previously documented for this type of forest in Antonović et al. (2012). Thus, it is highly unlikely that this forest type could support specialised peat bog species. The peat bog edge was identified based on vegetation structure and composition, and soil properties. It is the line joining the bases of first shrubs and trees belonging to non-peat bog vegetation communities. The average width of the peat bog edge was 10 m. Within each habitat 6 sites were selected, each sampled with 5 pitfall traps placed 5 m apart in a linear transect. Transects were at least 50 m apart. At each habitat a total of 30 pitfall traps were used. The traps (polythene cups, V = 300 mL) were partially filled with saturated sodium chloride solution and a drop of neutral-smelling detergent to reduce the surface tension. A Styrofoam roof was placed 10 cm above each trap to protect it from the rainfall and leaf litter. The samples were collected monthly, during one growing season from May to November of 2010.

Carabid beetles were identified to species and subspecies according to Turin et al. (2003) and Müller-Motzfeld (2006). *Pterostichus rhaeticus* and *P. nigrita* were identified using Luff (1990) and Angus et al. (2000), based on female and male genitalia. Nomenclature follows Vigna Taglianti (2013). All voucher specimens of carabid beetles are deposited in the first author's collection (Department of Biology, Zagreb). Ants were identified to the species level using Kutter (1977), Czechowski et al. (2002) and Seifert (2007). Nomenclature follows Radchenko (2013). Identified specimens are deposited at the laboratory of the Croatian Myrmecological Society, Zagreb.

Table 1
Vegetation analysis of the studied habitats at the Đon močvar peat bog (Blatuša, Croatia).

Vegetation analysis	Peat bog	Edge
Plant associations	*Drosero-Caricetum echinatae* Horvat (1950) 1962 *Rhynchosporetum albae* W. Koch 1926 *Phragmitetum australis* Schmale 1939	*Frangulo-Alnetum glutinosae* Rauš 1968 *Epimedio-Carpinetum betuli* (Ht.1938) Borh. 1963
Peat moss layer		
Dominant species	*Sphagnum palustre* L. *Sphagnum capillifolium* (Ehrh.) Hedw. *Sphagnum denticulatum* Brid.	*Sphagnum palustre* L. *Sphagnum angustifolium* (Russ.) C. Jens.
Abundance	18.17 (2.56)	3.50 (1.82)
Plant species richness	3.17 (0.60)	1.17 (0.48)
Herb layer		
Dominant species	*Rhynchospora alba* (L.) Vahl *Eriophorum angustifolium* Honck. *Phragmites australis* (Cav.) Trin. ex Steud.	*Carex acutiformis* Ehrh. *Carex brizoides* L. *Leucojum vernum* L.
Abundance	30.67 (3.07)	36.67 (7.17)
Plant species richness	9.17 (0.87)	13.00 (2.48)
Shrub layer		
Dominant species		*Frangula alnus* Mill.
Abundance	6.67 (2.23)	11.33 (1.63)
Plant species richness	2.50 (0.62)	2.50 (0.43)
Tree layer		
Dominant species	*Alnus glutinosa* (L.) Gaertner	*Alnus glutinosa* (L.) Gaertner *Betula pendula* Roth. *Carpinus betulus* L. *Quercus petraea* (Mattuschka) Liebl.
Abundance	3.83 (0.75)	11.83 (3.05)
Plant species richness	1.00 (0)	2.33 (0.71)
Molinia caerulea abundance	6.50 (0.81)	1.00 (0.68)
Species richness (S)	15.5 (0.92)	19.33 (9.91)
Shannon diversity (H') bits/ind.	2.62 (0.06)	2.77 (0.16)

*Numerical values of plant species analyses are represented with mean (SE) for six sites at each habitat type.

2.3. Vegetation analysis

Vegetation of the peat bog and adjacent edge habitats was sampled using phytosociological relevés according to standard Central European