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Natural peat bog remnants promote distinct spider assemblages and habitat specific traits

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ABSTRACT

Peat bogs are very sensitive and highly endangered ecosystems. They were once typical landscape elements in northern Germany, but today only a few remnants exist. On-going habitat degradation has alarming adverse effects on biodiversity, and, from a conservation viewpoint, it is imperative to evaluate the current ecological quality of the remaining peat bog remnants to assess the intensity of degradation and to suggest reasonable management strategies. In 2007, spiders were sampled in 23 study sites representing typical peat bog habitat types in the northern parts of Westphalia (NW Germany). In all, 214 species from 18,413 adult individuals have been collected. Multivariate analyses showed that different peat bog successional stages harbour distinct spider assemblages with succession being the main driver for species separation. *Pardosa sphagnicola*, *Pirata piscatorius* and *P. uliginosus* can be considered as flagship species for near-natural or natural peat bogs. Trait analyses showed that habitat specialisation for high moisture is negatively affected by succession. Peat bogs are now only small remnants, but, nevertheless, they have a high conservation value as they still harbour a distinct species assemblage and specialised species.

1. Introduction

Peat bogs in Central Europe are very sensitive and highly endangered ecosystems (Succow and Joosten, 2001; Riecken et al., 2006) and are thus listed in Annex I of the European Habitats Directive as a priority habitat type (Balzer and Ssymank, 2005). In northwestern Germany, peat bogs were once typical landscape elements and covered a large area in the 19th century (Dierßen and Dierßen, 2008). Peat bogs are stable and slowly changing ecosystems if natural conditions are preserved (Succow and Joosten, 2001). However, due to anthropogenic impacts, such as cultivation, peat cutting, afforestation, groundwater lowering, ploughing and fertilisation, as well as natural succession, today, only a few remnants of natural and near-natural undisturbed peat bogs remain in northwestern Germany (Succow and Joosten, 2001; Dierßen and Dierßen, 2008). Most are restricted to small areas and endangered by habitat loss and degradation, fragmentation and isolation (Dierßen and Dierßen, 2008).

From a conservation viewpoint, these developments have alarming adverse effects on biodiversity because bog habitats are ecologically valuable. They harbour specialised fauna and flora (Scott et al., 2006; Spitzer and Danks, 2006; Buchholz et al., 2009; Haase and Balkenhol, 2014), which benefit from the constant moisture provided as well as from moderate temperatures, shade, food organisms and refuge from predation (Koponen, 2000; Bruun and Toft, 2004; Glime and Lissner, 2013). The survival of these peat bog species depends on the habitat quality, and, thus, it is mandatory to assess the conservation status of these threatened habitats. This allows ensuring that the best remnants are preserved and the development of a reasonable habitat management (Scott et al., 2006; Buchholz et al., 2009). However, to reach this conservation aim, reliable data on species diversity and composition are required to assess the status quo (Spitzer and Danks, 2006). Furthermore, working out indicator species is mandatory to get a basis for impact assessments by analysing ecological shifts and the evaluation of restoration efforts. Finally, it is important to get a better understanding of the functional level, for example to analyse the effects of habitat filtering on the shaping of species communities (Schirmel et al., 2012). Habitat degradation may affect species traits differently, causing different species compositions in different degradation levels. This refers to the concept of Leibold et al. (2004), which presumes that local habitat templates can act as

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filters sorting species according to their functional traits. As a consequence, only species with functional traits that match the specific environment can pass these filters (Poff, 1997; Gerisch et al., 2012).

Due to their high reproductive rates, invertebrates such as spiders are very good early warning organisms and indicators (Kremen et al., 1993; Blaum et al., 2009). Therefore, several authors call for a more prominent use of invertebrates within the field of conservation studies (Dunn, 2005; Spitzer and Danks, 2006; Schuldt and Assmann, 2010). In this context, spiders play an important role in nearly all terrestrial ecosystems and, thus, have been successfully used as indicator organisms within wetland studies (e.g., Bruun and Toft, 2004; Platen, 2004; Scott et al., 2006; Cristofoli et al., 2010; Haase and Balkenhol, 2014), even at a small-scale (Komposch, 2000). In general, they are abundant, easy to record and inhabit a wide array of spatial and temporal niches (Wise, 1993; Entling et al., 2007). Spiders indicate the ecological status of biotic communities and changes in habitat and landscape structure (Buchholz, 2010; Schirmel et al., 2012).

Especially in the northern parts of Westphalia, where lowland peat bogs once covered large parts of the landscape, the assessment of arthropod diversity is valuable to evaluate the current ecological situation and the quality of the remaining peat bog remnants. It is mandatory to assess the intensity of degradation and to suggest reasonable management strategies. The main research questions of the present study are, therefore:

1. Do different peat bog successional stages harbour distinct spider assemblages, and are there unique assemblages in natural peat bogs?
2. Is it possible to define stage specific indicator species to assess the current intensity of degradation?
3. Which spider traits are filtered along the successional gradient, and to what extent do environmental variables affect habitat specialisation?

2. Methods

2.1. Study area

The study was conducted in four peat bogs in northwestern Germany. The areas were located near the town of Münster (North Rhine-Westphalia, Germany) at an elevation of 40–100 m asl. The climate in this region is suboceanic with an average annual temperature of 7.9 °C and an average annual precipitation of 758 mm (Murl NRW, 1989). The four study areas, Boltenmoor (34 ha; 52°03′N, 7°40′E), Borghorster Venn (98 ha; 52°9′N, 7°25′E), Emsdettener Venn (340 ha; 52°11′N, 7°27′E) and Venner Moor (150 ha; 51°51′N, 7°32′E) (Appendix S1), represented isolated and old peat bog areas in an intensively used landscape. All peat bogs were anthropogenically influenced and formed since the mid-19th century (e.g., afforestation, peat cutting, lowering of groundwater). Some parts have been restored, abandoned or left to succession. Thus, the study areas comprises typical natural or semi-natural moorland habitats such as peat bogs, *Molinia* bogs, bog forests and wet and dry heaths, as well as cultivated habitats like wet pastures and meadows.

2.2. Site selection and environmental data

In total, 23 study sites representing the typical peat bog habitat types were selected (Table 1). To characterise the study sites, seven environmental parameters were recorded. Vegetation structure was measured and estimated according to Sundermeier (1998a,b) by the following parameters: mean height of herbal layer [cm], average cover of trees [%] (estimated as a percentage of canopy density), herbal layer, mosses and litter. Soil humidity was estimated in the field according to AG Boden (1994). Soil acidity was determined using a pH-tracer (Merck).

Table 1
Characteristics of study sites in the peat bog areas, Boltenmoor (BM), Borghorster Venn (BV), Emsdettener Venn (EV) and Venner Moor (VM). Site abbreviations correspond to investigated habitat types, birch (Bi), bog forest (Bf), near natural peat bog (Bo), *Molinia* bog (Mo) and grassland (Gr). Vegetation structure: c.tree = cover of trees/canopy density [%], c.herb = cover of herbal layer [%], c.moss = cover of mosses [%], c.litt = cover of litter [%] and h.herb = height of herbal layer [cm]. Soil parameters: soil humidity with classes according to AG Boden (1994): 2 = slightly humid, 3 = humid, 4 = very humid, 5 = wet; soil pH.

Site	Area	Vegetation structure					Soil	
		c.tree	c.herb	c.moss	c.litt	h.herb	Humidity	pH
Bi1	BM	15	15	0	10	75	5	4.5
Bi2	BM	40	40	0	50	50	5	4.5
Bi3	VM	60	40	55	45	60	3	3.5
Bi4	VM	30	75	15	25	35	4	4
Bi5	BV	50	45	45	45	60	4	3
Bf1	BV	0	65	40	80	85	3	3.5
Bf2	BV	60	15	25	80	55	3	3
Bf3	BV	60	30	75	25	60	5	5
Bf4	EV	30	45	10	80	70	5	3.5
Bf5	EV	50	50	70	30	70	4	3.5
Bo1	BM	10	10	0	10	75	5	4.5
Bo2	VM	10	60	70	10	35	5	4.5
Bo3	EV	0	50	65	25	60	2	3
Bo4	EV	0	50	5	70	90	5	3.5
Bo5	EV	0	60	50	15	50	4	3
Mo1	BV	20	40	45	60	60	3	3.5
Mo2	BV	0	75	25	10	110	5	4.5
Mo3	BV	0	65	30	20	80	5	5
Mo4	EV	0	55	25	65	90	2	3
Mo5	EV	0	55	65	60	65	5	2.5
Gr1	EV	0	90	5	10	80	5	4.5
Gr2	EV	0	90	5	35	75	3	4
Gr3	EV	0	45	40	40	80	5	3

2.3. Sampling

Spiders were caught by means of pitfall traps. In each study site, four pitfall traps were installed randomly at a minimum distance of 15 m from each other. The traps were 500 ml plastic cups with a 90 mm diameter that were one-quarter filled with a 4% formalin-detergent solution. Sampling lasted from May to July 2007, and emptying was carried out every three weeks. Afterwards, all arthropods were sorted and transferred to 75% ethanol. Spiders were identified using the standard keys of Heimer and Nentwig (1991) and Roberts (1987, 1998). The nomenclature follows the World Spider Catalog (2015). All the juveniles were identified up to genus or family level but were not considered for subsequent analyses.

2.4. Data analysis

All statistical analyses were performed using the software environment R 3.0.1 (R Development Core Team, 2013). To carry out a statistical comparison of the study sites within the multivariate analyses, the data were standardised (individual numbers/number of sampling days/number of pitfall traps). Species with less than three individuals at a site were regarded as accidental species and, thus, were omitted from ordination but considered for trait analyses. Deleting rare species is a useful means to reduce the statistical noise in the data set without losing much information (McCune and Grace, 2002; Leyer and Wesche, 2007).

In order to detect groupings of the study sites, a total of 109 spider species were subjected to non-metric multidimensional scaling (NMDS) using the VEGAN package (Oksanen et al., 2015). For ordination, the relative species abundances were square root transformed. NMDS is an iterative ordination method that places samples in a *k*-dimensional space using the ranked distances among