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Short communication

Water mites as potential long-term bioindicators in formerly drained and rewetted raised bogs

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ABSTRACT

Many environmental studies of restored peatlands focus on biogeochemical cycles, productivity and decomposition. However, changes in the composition and structure of invertebrate assemblages in restored bogs have received little attention. In the present study we describe effects of rewetting on the water mite faunas (Acari: Hydrachnidia) of four raised bogs located in northwestern Germany. All examined peatlands had been drained in the past, and two of them had been subjected to peat extraction. The examined sites had been rewetted 2, 12, 14 and 25 years prior to our surveys, and currently represent different stages of plant succession. With increasing age after rewetting, the vegetation developed more complex structure as defined by *Sphagnum* status, and water mite fauna became somewhat similar to the fauna in an undisturbed raised reference bog. Water mites were found almost exclusively in bogs 25 years after wetting, and in these bogs they occurred in sites with more complex vegetation structure. Because water mites have high demands on abiotic and biotic factors due to their complex life cycle (i.e., the larvae are parasites, and the nymphs and adults are predators), we can infer that their mere presence irrespective of species abundance and richness reflects positive effects of the rewetting measures conducted in peat bogs.

1. Introduction

Water mites (Acari: Hydrachnidia) are a species-rich group of mites that inhabit a great diversity of freshwater habitats, with particular species adapted to lotic, lentic, hyporheic and other habitat types (Smith et al., 2009). The life cycle of most water mite species includes parasitic larvae, predatory adults and nymphs and two pupa-like inactive resting stages. This complex life cycle may be a reason for diverse needs of water mites for abiotic and biotic features of their environments (Di Sabatino et al., 2002; Więcek et al., 2013). Although water mites are still frequently omitted from most standardized collecting protocols in fresh waters (see e.g. Proctor, 2007), they have been shown to be useful bioindicators in springs (Gerecke and Di Sabatino, 1996; Martin and Brunke, 2012), running waters (Dohet et al., 2008; Gerecke and Schwoerbel, 1991) and, rarely, in some types of lentic waters (e.g. lakes; Biesiadka and Kowalik, 1991).

In Europe, acidic rain-fed raised bogs have been often investigated for terrestrial and aquatic macroinvertebrates (e.g. Peus, 1928; Rabeler, 1931), sometimes including water mites (e.g. Cichocka, 1998; Viets, 1938). Most of this research has been on bogs degraded due to human activities (draining, peat extraction). On the other hand, there are very few studies on raised bogs under more natural conditions not perturbed by humans (Van Duinen et al., 2003, 2006). Thus, precise measures to evaluate the success of restoration activities are somewhat vague, at least with regard to freshwater invertebrates. However, there is at least one thorough study on a near-natural raised bog, the Zehlau peat bog (Cichocka, 1996). Studies on regeneration of raised bogs have been carried out mainly in North America (Girard et al., 2002) and Europe (Farrell and Doyle, 2003). Effects of rewetting measures on assemblages of different groups of organisms were carried out for testate amoebae (Buttler et al., 1996), beetles (Watts et al., 2008) and aquatic rotifers, microcrustaceans and macroinvertebrates (Van Duinen et al., 2003, 2006).

We examined restoration sites differing in age located in raised bogs in northwestern Germany. We hypothesize that with increasing age the structure of vegetation should become more complex, and that water mite assemblages should move towards the target structure of an undisturbed raised bog. Our data come from a larger

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project carried out in northwestern Germany where various peat bogs were analyzed for their meiofauna and macroinvertebrates (Lipinski and Kiel, 2009, 2010). Our results suggest that in contrast to many other taxa, for which presence-absence is too coarse a measure, the mere presence of water mites in rewetted bogs may indicate stable conditions after restoration activities.

2. Materials and methods

The study sites are located in four Atlantic raised bog areas in northwestern Germany (Table 1). Although all the sites had been drained in the past, peat extraction had taken place only in Leegmoor (450 ha) and Stapeler Moor (557 ha). In the Dobbe (Ewiges Meer, 1180 ha) and Lengener Meer (245 ha), rewetting took place about 25 years ago and no extraction occurred. These two bogs with their well-developed floating mat margins are as close to their natural state as possible in terms of hydrological and structural conditions. In connection with degradation of most raised bogs in Europe by human activities, we used comparative data from the Zehlau peat bog according to Cichocka (1996).

A total of 312 samples were collected from eight sites in the four examined bogs in July and October 2005 and 2006 (Table 1). The selected study sites within each bog were of similar size (between 5 and 8 ha). Rewetting of the formerly drained remnant sites (Dobbe and Lengener Meer) required improving hydrological features, which was achieved by closing drainage ditches to dam up water and raise the water level in the bog (Göttlich and Averdieck, 1990). In contrast, rewetting of the large-scale peat extraction sites (Stapeler Moor and Leegmoor) started with building polders on the remaining black peat. In these polders, rain water is collected and water levels are regulated to be at least 30 cm above the peat surface to optimize *Sphagnum* development (e.g. Eggelmann and Blankenburg, 1993). At the starting point of rewetting, the studied remnant sites were characterized by the presence of vegetation and high habitat heterogeneity, while rewetting of the former peat extraction sites started off with establishing a homogeneous water body above bare peat soils. The bogs differed in the duration of time elapsed since they were restored and rewetted 2, 12, 14 or about 25 years prior to this study. Water and substrate quality, and vegetation structure also varied among the sites (Table 1; for details see Lipinski and Kiel, 2009, 2010).

In the studied peatlands, we set up transects 100 m long and 10 m wide that were divided into 20 subtransects (5 m × 10 m). Habitat structure was mapped within each transect, which reflected the wet–dry gradient. In each study plot, one subplot representative of the whole plot was selected for sampling of the aquatic and semiaquatic fauna. Except for very *Sphagnum*-rich sites (see below), each sample was collected five times with the use of a 10 L bucket (total = 50 L) with a distance of about 1 m between each sampling point. In each subplot, five of these 50 L samples were taken at random sampling points. The bucket was slowly submerged under water, at a constant speed, and to standardize the sampling procedure, all samples were taken by one person (A.L.). The content of the bucket (water, animals and vegetation) was poured through a 250 μm mesh. The material from study sites rich in *Sphagnum* mosses (e.g. floating mat margins) was taken with a grab sampler (Lipinski and Kiel, 2009). In the laboratory, water mites were sorted with a binocular microscope, preserved in 70% ethanol and identified to the species level (e.g. Gerecke, 2006; Viets, 1936). Abundance of oribatid mites (Sarcoptiformes: Oribatida) was also noted.

Water mite data sets were reduced to a presence-absence matrix to study differences between raised bog areas. A chi-squared test was used for analysis of differences between the individual study sites. All statistical analyses were performed using R 2.10.1

Table 1
Mean characteristics of the sites sampled in this study; the examined raised bogs and the areas within (with years after rewetting) are as follows: Dobbe in Ewiges Meer (Dobbe 25), Lengener Meer (LM 25), Leegmoor (Leeg 2, Leeg 14, Leeg 25), Stapeler Moor (Stap 2, Stap 12, Stap 25); we used comparative data from the Zehlau peat bog according to Cichocka (1996); habitat structure is abbreviated in the following categories: 1, open water; 2, floating *Sphagnum*; 3, closed *Sphagnum* cover; 4, *Sphagnum* mats; *n*, number of samples.

	Age of the particular sites in years								
	Leeg 2 *n* = 21	Stap 2 *n* = 15	Stap 12 *n* = 55	Leeg 14 *n* = 26	Leeg 25 *n* = 46	Stap 25 *n* = 44	LM 25 *n* = 51	Dobbe 25 *n* = 54	Zehlau bog *n* = 147
Hydrachnidia	–	–	*Arrenurus stecki*	–	*Hydrodroma despiciens*	*Arrenurus stecki*	–	*Limnesia connata, Arrenurus neumani, Hydrodroma despiciens*	*Hydrachna globosa, Limnochares aquatica, Hydrodroma despiciens, Limnesia fulgida, Arrenurus affinis, A. batillifer, A. neumani, A. cuspidator, A. maculator, A. tetracyphus, A. stecki*
Emergent vegetation	–	Little	*Eriophorum* sp., *Molinia coerulea*	*Eriophorum* sp., *Molinia coerulea*	*Eriophorum* sp., *Molinia coerulea*	*Eriophorum* sp., *Molinia coerulea*	–	–	*Eriophorum* sp., *Andromeda polifolia, Ledum palustre*
Peat extraction	+	+	+	+	+	+	–	–	–
Sphagnum development	1	1	1, 2, 3	4	1, 2, 3, 4	2, 3, 4	1, 2, 3	2, 3, 4	1, 2, 3, 4
Open water	+	+	+	+	+	–	+	+	+