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Evaluating the use of dominant microbial consumers (testate amoebae) as indicators of blanket peatland restoration

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ABSTRACT

Peatlands represent globally-important ecosystems and carbon stores. However, large areas of peatland have been drained for agriculture, or peat has been harvested for use as fuel or in horticulture. Increasingly, these landscapes are being restored through ditch blocking and rewetting primarily to improve biodiversity and promote peat accumulation. To date we have little knowledge of how these interventions influence the microbial communities in peatlands. We compared the responses of dominant microbial consumers (testate amoebae) to drainage ditch restoration relative to unblocked ditches in a UK upland blanket peatland (Migneint, North Wales). Two techniques were used for restoration: (i) dammed ditches with re-profiling; and (ii) dammed ditches with pools of open water behind each dam. Testate communities in the inter-ditch areas changed markedly over time and between treatments illustrating the potential of this group of organisms as indicators of blanket peatland restoration status. However, the responses of testate amoebae to peat rewetting associated with restoration were partially obscured by inter-annual variability in weather conditions through the course of the experiment. Although there was considerable variability in the response of testate amoebae communities to peatland drain blocking, there were clearly more pronounced changes in samples from the dammed and reprofiled treatments including an increase in diversity, and the appearance of unambiguous wet-indicator species in relatively high abundances (including *Amphitrema stenostoma*, *Archerella flavum*, *Arcella discoides* type, *Difflugia bacillifera* and *Difflugia bacillarium*). This reflects a shift towards overall wetter conditions across the site and the creation of new habitats. However, water-table was not a significant control on testate amoebae in this case, suggesting a poor relationship between water table and surface moisture in this sloping blanket peatland. Our findings highlight the potential of testate amoebae as bioindicators of peatland restoration success; however, there is a need for caution as mechanisms driving change in the microbial communities may be more complex than first assumed. Several factors need to be taken into account when implementing biomonitoring studies in peatlands including: (i) the natural variability of the peatland ecosystem under changing weather conditions; (ii) any disturbance connected with the restoration procedures; and (iii) the timescales over which the ecosystem responds to the management intervention. Our results also suggest an indicator species approach based on population dynamics may be more appropriate for biomonitoring peatland restoration than examining changes at the community level.

1. Introduction

Peatlands represent globally important habitats and carbon stores which are under threat from human activity and climate change (Holden et al., 2004; Charman et al., 2013; Swindles et al., 2015a). They store approximately one third of global soil carbon, whilst covering only approximately 3% of the land and freshwater surface (Holden, 2005). However, human activity has degraded peatlands through drainage and harvesting of peat in many parts of the world including NW Europe, North America, Russia and SE Asia (e.g., Baldock et al., 1984; Holden et al., 2004; Hooijer et al., 2010, 2012). This has led to recent efforts to re-wet peatlands in order to restore active peat-forming plant communities and promote carbon sequestration (e.g., Ramchunder et al., 2009; Parry et al., 2014).

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Blanket peatlands are found in hyperoceanic regions such as those of northern Europe, Alaska, Newfoundland, Tasmania, New Zealand, South America and Eastern Russia (Gallego-Sala and Prentice, 2012; Parry et al., 2014). There has been much research interest in blanket peatlands as it has been suggested they are at risk of progressive erosion and vegetation change as a result of climate change (Gallego-Sala et al., 2010; Li et al., 2016). In the UK, large areas of blanket peatland have become degraded from the effects of atmospheric pollution (Smart et al., 2010), peat extraction (Cruickshank et al., 1995), artificial drainage (Holden et al., 2006), grazing (Ellis and Tallis, 2001), prescribed burning and wildfire (Davies et al., 2010), afforestation (Wellock et al., 2011), and the construction of buildings and access tracks (Holden, 2005). Since the 1940s, many upland blanket peatlands in the UK have been drained through the excavation of ditches which aimed to lower water-table levels and increase land productivity (Holden et al., 2006). The excavation of ditches in blanket peatlands has driven a series of ecosystem-level changes to biodiversity, hydrology, and carbon sequestration, and in some locations has increased the flux of dissolved organic carbon (DOC) to water courses (Holden et al., 2006; Mitchell and McDonald, 1995; Ramchunder et al., 2012; Parry et al., 2014). To reduce the impacts of such management practices, ditch blocking with dams is now a commonplace restoration technique. The blocking of ditches is thought to lead to shallower water tables in peatlands, which can have positive effects on ecological diversity and carbon sequestration (e.g., Beadle et al., 2015). However, the timescales involved for any effects to become apparent after re-wetting are poorly understood, and the effects may be subtle (e.g., within the boundaries of natural variability). As large-scale field experiments are unlikely to exceed two-five years duration due to the availability of financial resources, bioindicators can be used to detect small changes that may not be apparent in hydrological or biogeochemical data (i.e., instrument-based monitoring).

There have been several studies examining the effects of peatland restoration on different groups of organisms including beetles, rotifers, microcrustaceans and macroinvertebrates (Van Duinen et al., 2003, 2006; Watts et al., 2008; Więcek et al., 2013; Beadle et al., 2015). Testate amoebae are a polyphyletic group of amoeboid protists characterised by the presence of a shell (test), and represent an important component of the soil microbial community. Testate amoebae are dominant microbial consumers in peatlands, representing 5–30% of the total microbial biomass, and can have a major influence on the ecological functioning of peatland ecosystems through nutrient cycling (Gilbert et al., 1998; Mitchell et al., 2003; Jassey et al., 2014). They have also been shown to be sensitive hydrological indicators in peatlands (Charman and Warner, 1992; Tolonen et al., 1994; Swindles et al., 2009, 2015b; Turner and Swindles, 2012). The response of testate amoebae to peatland restoration has been investigated previously based on analysis of cores of peat accumulated post-restoration (Buttler et al., 1996; Jauhiainen, 2002; Davis and Wilkinson, 2004; Valentine et al., 2013). There have also been some experimental studies examining the response of testate amoebae to hydrological change (e.g., Marcisz et al., 2014a,b). However, to date, there have not been any studies on blanket peatlands, and, critically, no time-series investigations of changes in surface testate amoebae before and after management intervention have been carried out relative to control systems. Here we investigate the responses of surface testate amoeba communities to restoration treatments in a UK upland blanket peatland (Migneint, North Wales). We examine changes in community composition, ecology, diversity and use these data to examine their potential as bioindicators of peatland restoration.

1.1. Hypotheses

We tested the following three hypotheses:

[H1]. Ditch blocking drives a change in testate amoebae at the community-level.

[H2]. Key wet-indicator taxa (e.g., wet indicators from the genera *Arcella* and *Archerella*) increase in response to restoration.

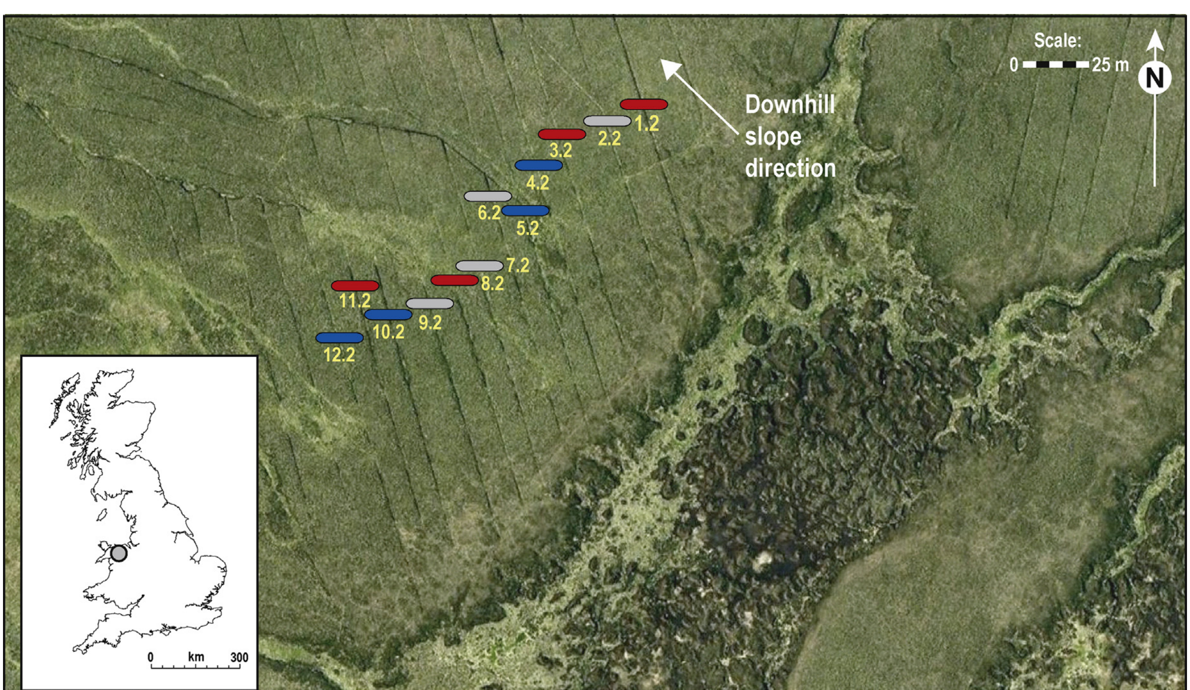

Fig. 1. Map of study site in the Migneint, North Wales. The location of each ditch is illustrated. The dipwells are located to the east (E) or west (W) of the ditch. Grey = control; Red = re-profiled; Blue = dammed.
Map data: Google, Getmapping PLC.