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Using palaeoecology to advise peatland conservation: An example from West Arkengarthdale, Yorkshire, UK

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ABSTRACT

Globally, peatlands are regarded as important carbon stores and their conservation essential for ensuring continuation of terrestrial carbon storage. Numerous peatlands in particular regions of Europe have been degraded by drainage, burning, extraction, overgrazing and pollution in recent decades, often leading to erosion, loss of peat mass and a loss of a variety of flora. In the UK, some 90% of peatlands can be regarded as degraded. Implemented restoration schemes have been aimed at blocking drainage ditches, re-vegetating bare peat or changing the present vegetation assemblage to a more 'desirable' alternative. Here we use palaeoecological techniques to reconstruct the development of a blanket peatland through its entirety with a particular focus on recent land management practices and their impact on vegetation in order to determine and support restoration targets. Analysis at West Arkengarthdale, Yorkshire, UK, shows that the present vegetation is not characteristic and has only been present for c. 200 years. Peat has been developing at the site for approximately 6700 years with *Sphagnum* particularly abundant between 0–40 cm depth (present day—450 cal. BP) and 150–190 cm depth (c. 3200–3900 cal. BP) and seldom recorded elsewhere in the core. A very recent change in *Sphagnum* composition is seen towards the surface of the profile, with *Sphagnum papillosum* making up 100% of the identified *Sphagnum* in the last 50 years. Monocots, Poaceae, *Rumex* and *Polytrichum commune* increase with the beginning of the industrial revolution and an increase in charcoal fragments is indicative of increased pollution and managed burning to support grouse management. It is suggested that any intention to alter land management at the site to encourage a greater variety of *Sphagnum* species and a decrease in *Calluna* is in line with peatland development at the site over the past 450 years. This collaborative approach between research palaeoecologists and conservation agency staff has wider application elsewhere.

1. Introduction

Globally, peatlands are estimated to contain between 270 and 370 Tg of carbon (TgC; 1 Tg = 10^{12} g) as peat (Turunen, Tomppo, Tolonen, & Reinikainen, 2002) and comprise approximately 3% of the Earth's surface (Limpens et al., 2008). Peatland ecosystems are degraded by many factors including erosion, prescribed burning, climate change, over-grazing, drainage, afforestation and peat-cutting. Blanket peats form in hyper-oceanic regions with high rainfall and low summer temperatures and can cover vast landscapes. These ecosystems are anoxic with low pH and nutrient availability and therefore plant and microbial life are adapted to these conditions. Plant productivity exceeds soil organic matter decomposition, so carbon is sequestered over time (Gallego-Sala and Prentice, 2013). Blanket peats are found across the globe in the high-latitude, oceanic fringes of all continents and it is estimated that 10–15% of global blanket bog is located in the British Isles (Tallis, Meade, & Hulme, 1997). Blanket peatland covers 1.5 million hectares in the UK with approximately 14% of this in England (Jackson and McLeod, 2000). These areas act as a net carbon sink and are the largest terrestrial carbon reserves in the UK (Blundell and Holden, 2015). Not only are UK peatland ecosystems considered to be of national and international importance (Lindsay et al., 1988; Bain et al., 2011) because they provide such an important terrestrial carbon storage but also because they also provide maintenance of biodiversity and protection of water resources (Drew et al., 2013; Lindsay et al., 1988).

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1.1. Peatland degradation

Blanket mires are particularly vulnerable to degradation and this has become widespread in parts of the UK uplands. Degradation is caused by a number of factors including blanket peat erosion, which is a three-stage process beginning with a disruption of the vegetation cover, leaving peat exposed. This is followed by reduced cohesiveness of the exposed peat caused by frost action and drought, leaving the peat surface layer easily eroded by wind, water or oxidation (Yeloff, Labadz, & Hunt, 2006).

Tallis published a series of papers on peat erosion in the Pennines with extensive erosion being reported at Featherbed Moss (Tallis, 1985) and Holme Moss (Tallis, 1987) with the intention of informing management. Mackay and Tallis' (1996) have also focussed on erosion within the area with a study on the disappearance of *Sphagna* from sites on Fairsnape Fell, demonstrating the extent of the issue, specifically in the Pennines. Peat erosion can be worsened by over-grazing by sheep and studies have shown that on blanket mire, keeping more than one sheep per hectare increases the area of bare ground, carrying an increased risk of damage by erosion (Cooper, McCann, & Hamill, 2001). However, it is important to consider that the effect may vary depending on the breed and age of the sheep and the timing of grazing.

A contentious current issue in nature conservation in the UK is the prescribed burning of blanket bog, which has been used to manage vegetation growth in these ecosystems for centuries. However, its use has increased over approximately the last 200 years for both sheep and grouse management (Muller et al., 2012). Continued 'Global Warming' and the subsequent increase in evapotranspiration may well lead to lowered water tables in peatlands and an increase in wildfire frequency (Hogg, Lieffers, & Wein, 1992), particularly given that average daily temperatures are projected to increase by 1.8 °C by the 2050s for the South Pennines, Yorkshire Dales and North York Moors (Yorkshire-Futures et al., 2009). Furthermore, changes in precipitation patterns and warming are expected to affect peat bog vegetation composition and thereby its long-term carbon sequestration capacity.

Peatlands are naturally rich in organic acids but are also at risk from acid rain, particularly those in close proximity to industrial areas. Increases in sulphur (SO_2, H_2SO_4 and SO_{42}) deposition (Ferguson, Lee, & Bell, 1978) over 200 years of industrialisation have been linked with losses of bryophytes and a decrease in species diversity, particularly since the mid-19th century. Recent studies have also shown that the degree of acid rain deposition onto peat bogs may be particularly important in regulating the production and emission of CH_4 from peat (Nedwell & Watson, 1995; Watson & Nedwell, 1998; Gauci, Dise, & Fowler, 2002). Peat is often cut to be used as fuel and the amount of peat cut from peatlands was much less until the introduction of tractor-powered peat-harvesters in the early 1980s in Northern Ireland. The effects of peat cutting using machinery include a reduction in canopy height, biomass and species diversity. Few peatlands recover following such disturbance with many remaining barren of vegetation 10 years after harvesting ends (Cooper et al., 2001). Peatlands may also be subject to deliberate drainage, with one of the main aims being to benefit the growth of *Calluna vulgaris* to improve the habitat for grouse and sheep; however, any enhancements in the nutritional value of *C. vulgaris* can be counterbalanced by the decline in cover and the spread of unpalatable grasses. Investigations have also shown that plant species dependent on high water tables such as *Sphagnum* spp. have a lower abundance when closer to drains (Ramchunder, Brown, & Holden, 2009).

Many of the factors leading to the degradation of peatlands are interlinked, with drainage and over-grazing leading to erosion and wildfire. This in turn increases the rate of erosion, leading to increased carbon dioxide and methane entering the atmosphere and increased dissolved organic carbon (DOC) from peatlands entering water sources (Page et al., 2002). Degradation and erosion of these areas has significant ecological effects including loss of habitat and reduction of biodiversity (Yeo, 1997). It is predicted that they will show heightened sensitivity to disturbance as a result of climatic change and increasing erosion over the coming decades (Davies and Bunting, 2010). Current restoration techniques include blocking drains and re-vegetating; however, how these areas are re-vegetated, to what end, and with which species is where palaeoecological studies can assist.

1.2. Using palaeoecology to advise conservation

It has been suggested that long-term datasets generated through palaeoecological techniques could be of use in nature conservation (Birks, 1996, 2012; Froyd & Willis, 2008; Davies & Bunting, 2010; Hjelle, Kaland, Kvamme, Lødøen, & Natlandsmyr, 2012; Muller et al., 2012; Willis, Bailey, Bhagwat, & Birks, 2010; Wilmshurst et al., 2014). Palaeoecology can provide the long-term ecological background to help answer questions covering the more recent time periods of principal interest to conservationists (Chambers, Mauquoy, & Todd, 1999; Chambers and Daniell, 2011; Seddon et al., 2014). Palaeoecological approaches can assist when considering the trajectories and driver of changes through time, can aid understanding of the nature of any departure from 'normal' conditions, and provide early warnings of future change (Finlayson, Clarke, Davidson, & Gell, 2015).

Early examples of palaeoecological studies to aid conservationists in the UK include research in the 1970s in Cumbria (Oldfield, 1970) and Upper Teesdale (Turner, Hewetson, Hibbert, Lowry, & Chambers, 1973) with a pause in such research during the 1980s before it resumes in the 1990s with a paper by Huntley (1991), followed by work on Exmoor (Chambers et al., 1999), in Wales (Chambers, Mauquoy, Cloutman, Daniell, & Jones, 2007; Chambers, Mauquoy, Gent et al., 2007), Scotland (Davies and Watson, 2007), Northern England (Chambers and Daniell, 2011) and the Pennines (Davies, 2015), with encouraging results. More recently, three further studies have been conducted in Yorkshire at Keighley Moor, by Blundell and Holden (2015); at Mossdale Moor, by McCarroll, Chambers, Webb, and Thom (2015); and at Oxenhope Moor by McCarroll (2015). The present vegetation at Keighley Moor has only been characteristic for the last c. 100 years (Blundell and Holden, 2015), whereas at Oxenhope Moor, human influence began 2100 cal. BP with the current vegetation being characteristic for 300 years (McCarroll, 2015) and at Mossdale Moor, a long history of human influence was observed with an intensification in human activity where a substantial charcoal increase is interpreted as recent (<450 years) management practices (McCarroll et al., 2015).

1.3. Site selection and description

The present study reports the results of palaeoecological reconstructions of West Arkengarthdale, Yorkshire, UK. This was conducted in collaboration with the Yorkshire Peat Partnership (YPP: an organisation run by the Yorkshire Wildlife Trust that restores and conserves upland peat resources in order to ensure the long-term future of these ecosystems) with a view to supporting and informing the practical moorland conservation work by determining the former vegetation of this degraded peatland.

The site was selected for palaeoecological analysis by the YPP based on the current judgement that it occupies a more desirable state when compared to other sites managed by the organisation. The site was also assessed by the authors to establish whether it was suitable for palaeoecological analysis. This study aims to aid understanding of vegetation changes throughout the peat profile,