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Educational potential of peatlands and prehistoric bog oaks in Lancashire and adjoining regions

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Abstract

This paper documents recent projects where peatlands and bog oak discoveries have been at the heart of both education and research at Manchester Metropolitan University. Peatlands are numerous in the Manchester and surrounding areas and have been exploited over millennia. Peat removal has uncovered the remains of prehistoric woodlands, and bog oaks are now the focus of undergraduate research, revealing the nature of the prehistoric environment. Currently postgraduate research aims to optimise conditions for the successful re-vegetation of peat surfaces, reflecting a shift in attitudes from peatland exploitation to restoration. Organizations such as the Lancashire Wildlife Trust, Natural England and Manchester Metropolitan University have been at the forefront of recent initiatives to conserve and enhance peatlands, as well as to communicate their values: palaeoecological, wildlife and biodiversity, ability to store carbon as a buffer against climate change, water storage, recreational and amenity. Initiatives such as the Chat Moss and Accessing Manchester's Mosslands Projects are highlighted as examples of good practice in communicating peatland values and research to wider audiences. Educational initiatives embracing peatlands in the curricula and research are key to producing knowledgeable and enthusiastic future champions of our peatlands.

Key Words

Wetlands, north-west England, conservation, ecology, climate change, UAV mapping, dendrochronology, augmented reality

1.0 Introduction

1.1 Peat & Peatlands in NW England

Peat is partially decomposed plant remains preserved in waterlogged environments that are anaerobic or lacking in oxygen. Peatlands in the UK comprise mostly upland blanket peats and lowland raised bogs found in the wetter western and northern areas (Lindsay *et al.*, 1988), and estimates suggest that peat originally covered between 1.5 – 1.6 million ha in the UK, around 0.9 – 1.5% of the area covered by peatlands in Europe (Charman, 2002).

In north-west England pre-peat lowland landscapes were shaped during the Devensian glacial period, leaving surface geology dominated by sands, gravels and till (British Geological Survey, 2017). Today the undulating topography of the Cheshire and Lancashire plains is dotted with meres (lakes) and mosses (peat bogs) that have developed in areas of impeded drainage (Figure 3). Although some of these wetlands have developed naturally, humans are also thought to have contributed to peat formation through environmental modifications in combination with increasingly wet climatic conditions (Charman, 2002: 73-91).

Over millennia peatlands, particularly lowland raised bogs and the upland blanket mires, have suffered degradation. Initially this was small-scale from the hand-cutting of peat for domestic fuel, but impacts escalated including the grazing of livestock and since the Industrial Revolution the effects of atmospheric pollution on peatland vegetation (Tallis, 1999). The mechanised extraction of peat for horticulture has been particularly problematic since the mid-twentieth century, and although peatlands cover 12% of the UK, 80% of this area is currently in 'poor condition' (The Wildlife Trusts, 2017). In the Manchester Mossland area only c.300 ha of 'intact' peatlands remain (The Wildlife Trusts, 2014), including Holcroft Moss (Figure 1). Upper peat layers at Holcroft contain pollutants associated with the Industrial Revolution, data revealed through recent research-informed teaching at Manchester Metropolitan University.

The values of peatlands include their rich flora and fauna (biodiversity), their roles in water storage, flood prevention, as carbon stores (actively growing bogs removing CO_2 from the atmosphere and combatting the negative effects of global warming) and as recreational and amenity resources (Lindsay *et al*., 1988; Charman, 2002; Glenk *et al*., 2014). Peatland restoration is therefore a current conservation priority (Anderson, 2014) and throughout the north-west a number of organizations at the forefront of peatland management and restoration, including conservation charities (e.g. Wildlife Trusts, RSPB) and government agencies (e.g. Natural England). For wetlands in the Manchester area the Great Manchester Wetlands Partnership (GMWP) has been established to coordinate this work and projects of partner organisations. The partnership is coordinated by the Lancashire Wildlife Trust (LWT), and also includes government agencies, companies, local universities and local authorities.

A recent initiative overseen by GMWP has been the Great Manchester Wetlands Scheme, a major peatland acquisition and restoration project covering c. 40,000 ha. An important initiative within the Greater Manchester Wetland Scheme is the Heritage Lottery-funded Chat Moss Project (CMP). This £1.9 million project running between August 2012 and August 2017 aims to engage local communities in all aspects of habitat restoration, conservation and appreciation of these mosslands as an amenity (LWT, 2017a). Examples of projects and events associated with CMP are the Accessing Manchester's Mosslands Project and the Chat Moss Bog Oak Festival – featured below.

1.2 Accessing Manchester's Mosslands (AMM) – Little Woolden Moss

Peatlands are not only important for their present wildlife, but their accumulating layers contain unique records of past flora and fauna (palaeoecology). These environmental records can stretch back thousands of years and include evidence of past climate change and human impacts on the environment.

Little Woolden Moss (LWM), covering 107ha c.2 km WNW of Irlam (Figures 2 & 3), is a remnant of a much larger peatland area (known as Chat Moss), and has been the subject of peat extraction over many decades. In 2017, whilst commercial peat extraction continues for a limited time on western parts of the site, much of the area is now covered by a thin (c.50cm) layer of peat and is managed for conservation by LWT. The site was purchased by LWT in 2012 and forms a key part of the CMP and its associated peatland restoration.

Peat extraction at Little Woolden Moss has revealed the remains of a prehistoric woodland preserved by basal peats. Currently discarded stumps and trunks lie individually and in piles on shallow peat where commercial peat cutting has ended (Figure 4b), and in places these subfossil tree remains can also be found *in situ* in their original growth positions (Figure 5). In 2015 an application was made to the Manchester Geographical Society (MGS) to fund University-led research (AMM Project) that aimed to record the nature of the LWM prehistoric woodland (spatially and the individual nature of stumps and trunks), to find out the age of the woodland and to publicise the palaeoenvironmental archives of Manchester's Mosslands. The project has been jointly funded by the MGS and Manchester Metropolitan University. The sampling and dating of the LWM prehistoric woodland is discussed in the section on *Undergraduate Research* below.

1.3 Martin Mere – palaeoecology & environmental education

Martin Mere is a series of peatlands, marshes and areas of open water located 11 km to the east of Southport, Lancashire (Figure 3). It is likely to have formed and subsequently developed naturally in the post-Glacial landscape, but in recent centuries it has been subjected to significant human modification. In the sixteenth century the traveller John Leland reported that the mere or lake covered an area of four by three miles (Toulmin Smith, 1964, cited in Hale & Coney, 2005 p.1), 'the largest lake in England' (Hale & Coney, 2005 p.1). Since the eighteenth century and possibly earlier, there have been significant efforts to drain the lake, turning it and surrounding marshland into agricultural production. The area known today as Martin Mere is only a small remnant of its former self and is managed for conservation by the Wetland and Wildfowl Trust enhancing and creating habitats for wading birds and other wetland species (WWT 2017).

Finds of subfossil bog oak trees at Martin Mere have also been the focus of recent research at Manchester Metropolitan University and their dating and potential as a future educational resource is also discussed in the section on *Undergraduate Research* below.

2.0 Manchester Metropolitan University: teaching & research

Peatland Restoration & Students

In their efforts to involve local communities in the Chat Moss Project, Lancashire Wildlife Trust has sought to engage local Universities. This, as well as Manchester Metropolitan University's ambition to increase opportunities

for student work experience, led to five Manchester Metropolitan undergraduate 9 month placements (2013-2016) dedicated to assisting in conservation management and in community outreach activities (Figure 4a). The success of these placements has been measured by student involvement in a wide range of activities: leading parties of conservation volunteers, undertaking project management, environmental monitoring and ecological surveys, maintaining databases, contributing to funding applications, updating LWT blogs and Facebook pages and in environmental education with local schools and the local community. On return to University these students have regularly demonstrated improved academic performance and in one case a peatland-related undergraduate research project has led to subsequent postgraduate studies (see *Sphagnum restoration* below; Keightley *et al*., 2016).

Both degraded and more intact peatland ecosystems have also been utilised in undergraduate fieldtrips, associated laboratory work and teaching. Blanket peat at Holme Moss in the south Pennines has been the focus of a major research programme relating to peatland restoration (Elliott *et al*., 2015; Rosenburgh, 2016) and has also served as a location to demonstrate both practical ecology, conservation and re-vegetation techniques, as well as palaeoecology (Figure 5a). The latter has been illustrated by taking peat cores in the field and analysing pollen preserved in the peat to reconstruct recent vegetation history. This in conjunction with analyses of peat chemistry has exemplified the impacts of industrial pollution since c. AD 1750-1800 on peatland vegetation (Manchester Metropolitan University final year unit 'Global Environmental Change and Ecosystem Response'). More recently similar learning opportunities have been realized in comparisons of Holcroft Moss (Figures 1 & 5b), a more intact lowland raised mire, and the degraded peatland ecosystem at LWM.

2.1 Little Woolden Moss: aging bog oak woodland

In summer 2016 Callum Hayles, BSc Hons Environmental Science (Sandwich), took part in a field survey at LWM as part of the Accessing Manchester's Mosslands Project. Subsequently disc samples were retrieved using a chainsaw from the remains of prehistoric oak trees (trunks and stumps of Quercus spp. – Figure 6a & 6b; LWT 2017b). A total of 37 subfossil tree samples were retrieved from LWM (35 bog oaks, 2 bog pines). These were allowed to air dry, were down-sized by splitting and sawing, and were then surfaced using a belt sander to clearly differentiate the tree-rings (Figure 6c). Ring-width measurements were then made by Hayles in the Dendrochronology Laboratory at Manchester Metropolitan University (Figure 6d).

The measurements for each sample can be displayed in graph form (a ring-width curve) illustrating series of narrow and wide rings (Figure 7). Ring-width records for individual trees from LWM were compared with each other in a process called cross-matching and the ring-width data from trees shown to have grown at the same time were averaged to create a mean growth record or a tree ring chronology (e.g. LWM2_1, see Figure 7). Four site chronologies were produced for LWM and data from these were sent to the Dendrochronology Laboratory at Queens University, Belfast for comparison against their database of reference chronologies from other sites throughout the UK and Ireland (Brown & Baillie, 1992; Baillie 1995). Results of these data comparisons showed that the subfossil oak trees from LWM had very similar growth patterns to bog oaks previously sampled from Eskham House Farm in Lancashire, and consequently, the prehistoric oak woodland at LWM is known to have grown between 3545 and 3178 calendar years BC (a minimum age-range that may be extended by future sampling and analyses).

Hayles' research project was completed in summer 2017 and contained a fuller explanation of the dating of the prehistoric woodland from LWM. These findings will be placed in the context of previously published vegetational records from Lancashire and further-a-field (cf Pilcher 1990; Pilcher *et al* 1996; Atkinson *et al* 1999; Innes *et al*. 1999; Bell *et al* 2001; Boswijk & Whitehouse 2002; Leuschner *et al*. 2002; Eckstein *et al* 2010; Lageard & Ryan 2013) forming part of an envisaged future publication. Further palaeoecological research is also planned in which peat samples and the pollen grains contained therein will be used to recreate the vegetation history associated with LWM and the surrounding region.

2.2 Recording Ancient Trees at LWM

UAV mapping

Funding from the Accessing Manchester's Mosslands Project facilitated the purchase of a drone / UAV (unmanned aerial vehicle – Figure 8) for mapping bog oak occurrences at LWM. It is hoped to map areas of LWM using images captured by UAV in summer 2017. Resultant data will be used to create a digital surface model revealing the locations of *in situ* subfossil trunks and stumps (Figure 9) in relation to current topography.

Augmented Reality (AR)

Three-dimensional real time imaging or augmented reality is a recent advancement in the field of virtual reality. It has wide-ranging applications, for example from enhancing surgical procedures (cf. Qu *et al*. 2015) to generating 3-dimensional images of products to enhance marketing strategies (cf the Lego Digital Box, METAIO, 2015). AR has been used in specifically environmental / geographical contexts for example to create virtual scenery to facilitate groundwater simulations (Zehner *et al*. 2012), the dynamic spread of vegetation (Ghadirian & Bishop, 2008) and in educational settings creating interactive visualisation frameworks to present geographical information from indoor and outdoor environments (Liarokapis *et al*. 2005).

Bog oak trees revealed at LWM were often removed from their preservational environment and are currently deteriorating rapidly and also disappearing under revegetating bare peat surfaces. A primary aim of the AMM Project was to create 3-dimensional visualizations of bog oak trunks and stumps so that current and future generations will be able to understand the forms of these prehistoric trees. Digital images were taken from a series of consecutive locations surrounding each trunk or stump, with the bog oak as their focus. The images were then combined using specialist AR software (Wikitude) to create an AR image. Figure 10 shows two AR images of bog oaks that have been created for a bog oak stump and a trunk from LWM and if the instructions below each image are followed (including downloading the Wikitude App) the bog oak image can then be viewed in 3-D AR ideally on a smart phone or tablet. The AR images have been reproduced on a range of publicity / educational materials from cardboard courtesy cards to posters. The longer-term aim of this work is to develop additional AR resources such as interactive maps and posters in conjunction with the LWT.

2.3 Martin Mere: aging bog oak woodland / an educational resource

Bog oaks have also emerged over a number of years from the Wetland and Wildfowl Trust (WWT) site at Martin Mere (Figure 3). These were originally unearthed by peat cutting and agricultural drainage, but more recently by management activities designed to enhance habitats for birds. Twenty *ex situ* bog oak trunks and stumps were sampled in July 2016 (Figure 11a & 11b) for an undergraduate final year project undertaken by Emma Clarke, BSc Hons Physical Geography (Sandwich). These tree samples have been prepared as documented above for LWM and measured by Clarke. Cross-matching the ring-width records for individual trees led to the construction of 4 site tree ring chronologies and comparison with reference chronologies held at Belfast also led to successful tree-ring dating. Bog oaks from Martin Mere grew in the periods 4147 - 3954BC, 3652 - 3505BC, 2612- 2509BC and 1934 - 1738BC (dated against Lancashire reference chronologies from New House Farm, Hill Farm and the last two series from Croston Moss). As at LWM these results will be placed in the broader context of vegetation history in the region and it is also envisaged that these interpretations can form the basis for a future publication and informed environmental education for a wider audience via the WWT.

2.4 Identifying Sphagnum spores

Another peatland-related final year project in 2016-17 was undertaken by Thomas Briggs (BSc Hons Physical Geography). Microscopic spores of the bog moss (Sphagnum spp.) are routinely found in peat cores by researchers aiming to reconstruct vegetation history, and their presence is generally interpreted as an indication of a wet environment - Sphagnum is an important peat-forming plant. 34 different species of Sphagna have been recognised in the UK and in Ireland, and many of these are associated with sensitivity to pollution or preferences for specific peatland habitats, for instance growing on hummocks or in hollows. Using up-to-date imaging equipment and Geographical Information software, this project hoped to define criteria based on spore size and surface patterns (Figure 12) that allow key species of Sphagna to be identified from spores preserved in peat cores building on related research reported previously in the literature (Terasmae 1955; Tallis 1962; Cao & Vitt 1986).

2.5 Sphagnum restoration

Restoration of Sphagnum moss and related ecological function is a major goal of management work on LWM and this was the focus of Anna Keightley's studies when she commenced a placement, as part of her BSc Environmental Science (Sandwich) degree, with LWT's Chat Moss Project in 2013. With LWT she gained a broad range of practical conservation skills, particularly related to peatland restoration, and volunteer leadership experience. While on placement, Keightley designed and undertook long-term work for her dissertation project on *Sphagnum* propagation using fragments grown in a poly-tunnel and in field conditions, which incorporated hydrological monitoring and peat chemical analysis. The poly-tunnel she erected in 2013 is still used extensively for community group visits, as a shelter for volunteer work parties and propagation of *Sphagnum* (as seen on BBC TV in February 2017) as part of

ongoing site restoration. *Sphagnum* moss is a vital component in restoring a semblance of natural ecohydrological properties to a degraded peatland, but natural colonisation is hindered by a lack of local source material and hence there is a need for artificial re-introduction. Results from the project have helped to determine species selection and propagation methods used at the LWM reserve.

Keightley was introduced by her dissertation supervisor, Simon Caporn, to Micropropagation Services (EM) Ltd, which produces a range of micro-propagated *Sphagnum* products, designed to create a rapid, disease-free cover of *Sphagnum* for both conservation and paludiculture purposes, and she helped set up and monitor trial plots of these products on the Cadishead and Little Woolden Moss reserve. After successful trial results, wide-spread application of micro-propagated *Sphagnum* material (BeadaGel™) is in progress. She continued this collaboration in 2015 by starting an MSc, and subsequently a PhD, supported by Micropropagation Services, into greenhouse gas fluxes on degraded peatlands restored with BeadaGel™, on Cadishead Moss (Figure 13). She now leads a volunteer group, *The Sphagnum Squad*, responsible for vegetation restoration, chairs a Friends group that supports the Chat Moss Project with ongoing conservation, community engagement and fund-raising.

2.6 Peatland Publicity

Both the Lancashire Wildlife Trust and Manchester Metropolitan University have sought in recent years to publicise the importance of peatlands. This has been achieved through a range of individual projects as detailed above, but also via specifically targeted events and initiatives.

LWT has strived to make local people within Salford and its surrounding communities understand, respect and interact with their local peatlands, which were previously relatively unknown and inaccessible landscapes. The Chat Moss Project has placed an emphasis on providing informative presentations, family-oriented and community-lead events, experiencing peatlands through volunteering (conservation/restoration work), and on educational sessions for children and young people (exploring the physiology of peat, natural and human histories and unique wildlife).

To further these, LWT has formed close partnerships with local schools and youth, sporting and healthy lifestyle groups, and has also created an easily accessible online presence. Key tools in the latter have been social media, including Facebook, Twitter and Instagram, local / national radio and television, all helping to reach a contemporary audience. The success and scale of these outreach activities can be seen in Table 1.

The School of Science and the Environment (Manchester Metropolitan University) has also engaged in peatland publicity with the 'Science and Beauty of Peatlands' event held at the Hulme Community Garden Centre which formed part of the Manchester Science Festival in 2016 (Manchester Science Festival, 2017; Figure 14a). This involved researchers, undergraduate and postgraduate students and other contributions from LWT, a spatial poet and the archaeologist who discovered Lindow Man, the Iron Age bog body found to the west of Wilmslow in 1984 (Figures 15a & 15b). The dating of bog oaks from LWM, detailed above, not only featured at the Manchester Science Festival event, but also appears in an online blog (LWT, 2017b), and was the focus of a series of community outreach events comprising the 'Chat Moss Bog Oak Festival' (Figure 14b) held at Little Woolden Moss and St Mary's Church Hall, Cadishead in June 2017.

3.0 Discussion & Conclusion

The previous content has demonstrated that there is a close association between peatlands in north-west England and research, teaching and learning at Manchester Metropolitan University. This clearly aligns with the growing prominence of environmental issues in Higher Education curricula, particularly since the 1980s, as well as in the overall operations management of universities (Meredith & Stubbs, 2014; MMU Environment Team, 2017). However, whilst peatlands are the focus of on-going national and international research including experiments designed to

Table 1: Community engagement as part of the HLF-funded Chat Moss Project between 1.9.2012 and 6.12.2016 (Data courtesy of Lancashire Wildlife Trust).

	Meet the Team and Trails Events	Catalyst Youth Projects	Wild Families	Schools	TOTAL
Number of people	3142	832	1191	2356	**7521**
Number of events	89	75	29	77	**270**

understand and predict ecosystem responses to climate change (Elliott *et al*., 2015; Caporn *et al*., 2016; Higginbottom *et al*., in prep.), and research to inform peatland restoration (Keigthley *et al*., 2016; Rosenburgh, 2016), there remains the considerable challenge of communicating the value of peatlands to wider audiences.

A peatland inquiry conducted by the International Union for the Conservation of Nature (UK) highlighted nationally coordinated and funded peatland accounting, support for a UK peatland hub for information, trans-disciplinary research on peatlands, but also importantly 'communicating the importance of peatlands by highlighting their benefits to society' in their priority recommendations (IUCN UK, 2011 p.13). There is however often a miss-match between academic research and the communication of its often quite technical findings, peatland values and conservation priorities, to the general public (Albrecht & Ratamäki, 2016). Key principles, such as sustainability, are often poorly understood, in and outside academia, and even when they are embraced, a certain fatigue has set in with present generations often seemingly far removed from the environmental impacts that will affect future generations. This point is underlined, not only by the continued commercial horticultural use of peat, but by the even greater volumes of peat still used, under various guises, by gardeners in the UK (Alexander & Williams, 2013) and also in peatland conservation debates throughout Europe (Tolvanen *et al*., 2012).

Encouragingly, the application of social science methods to understanding and communicating environmental knowledge is increasingly coming to the fore. Conservation social science is now a recognised academic field that promotes human engagement, one of the 'key facilitators of improved conservation' (Bennett *et al*., 2017). Projects such as Accessing Manchester's Mosslands aims not only to generate detailed palaeoecological data promoting understanding of vegetation history and past landscape change and informing present-day conservation (cf. Blundell & Holden, 2015; McCarroll *et al*., 2016), but also to communicate these to local communities. Not everyone understands what is meant by the term 'bog oak', but the visualization through augmented reality of prehistoric tree stumps and trunks is one example of how innovative ICT methods can be used to enthuse and engage: 'wow, look at that … how old is that? How do you know?'

Peatland-related projects are on-going at Manchester Metropolitan University and it is hoped that initiatives such as the Accessing Manchester's Mosslands Project can be broadened to a wider audience through continued collaborations with organizations such as LWT and Natural England. Indeed Manchester Metropolitan University and Natural England have recently successfully completed a multi-disciplinary project titled 'Developing a wetland ecological network: mapping and spatial analyses for the Great Manchester Wetlands' (Higginbottom *et al*., in prep.). The key challenges for those involved in understanding, protecting and enhancing peatlands are to enthuse wider audiences, and this paper has outlined novel approaches, such as the use of augmented reality, which might provide useful tools in this respect. It has also highlighted the key role that is, and will be played into the future by Higher Education institutions in producing knowledgeable and enthusiastic champions of peatlands.

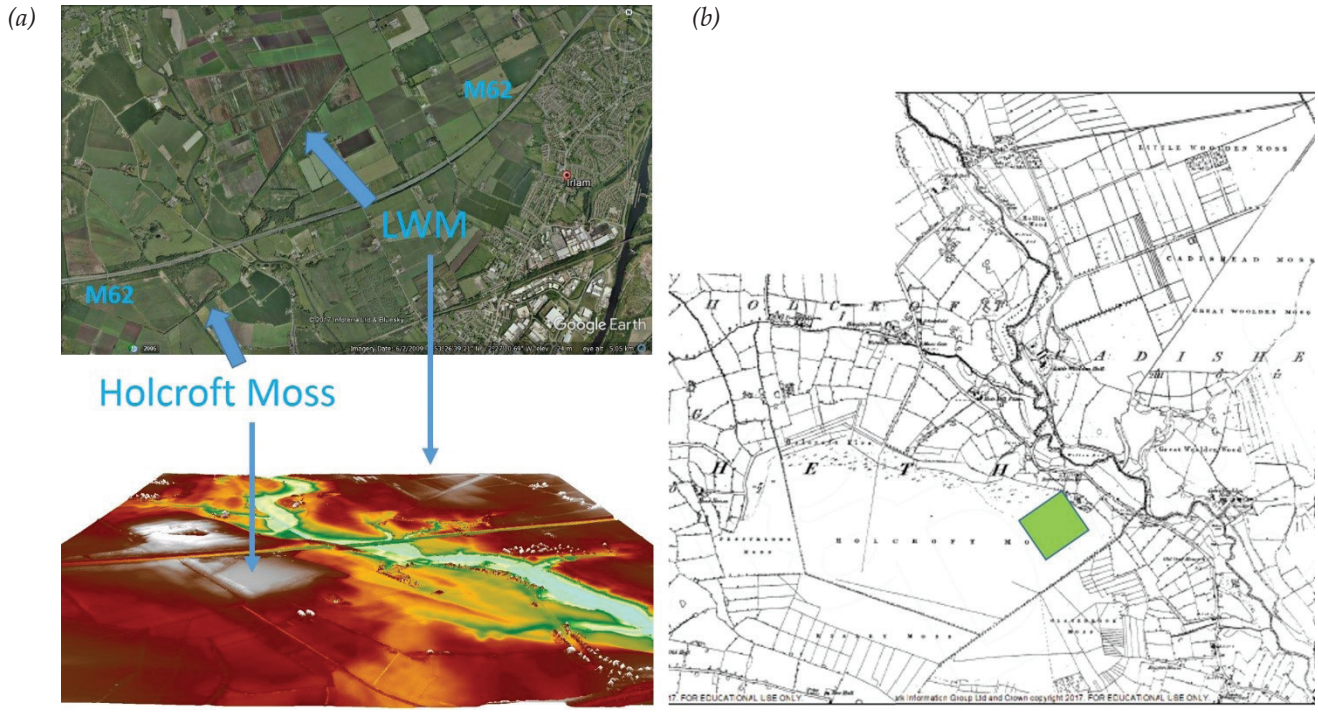


Figure 1a: A digital surface model (DSM) of present-day Holcroft Moss illustrating how its surface, shown in false colour (white), rises to the south-west away from the M62 motorway (LWM = Little Woolden Moss); and 1b: 1840 Ordnance Survey map showing the then much more extensive area of Holcroft Moss defined by radiating drains/field boundaries and a green rectangle illustrating the approximate area covered by Holcroft Moss today (Data courtesy: Google Earth, DSM © Crown Copyright and Database Right 2017. Ordnance Survey (Digimap licence) for educational use only).

Figure 2: Little Woolden Moss (red boundary) and Cadishead Moss (blue boundary), parts of the Chat Moss peatland complex to the west of Manchester (Image: Google Earth).

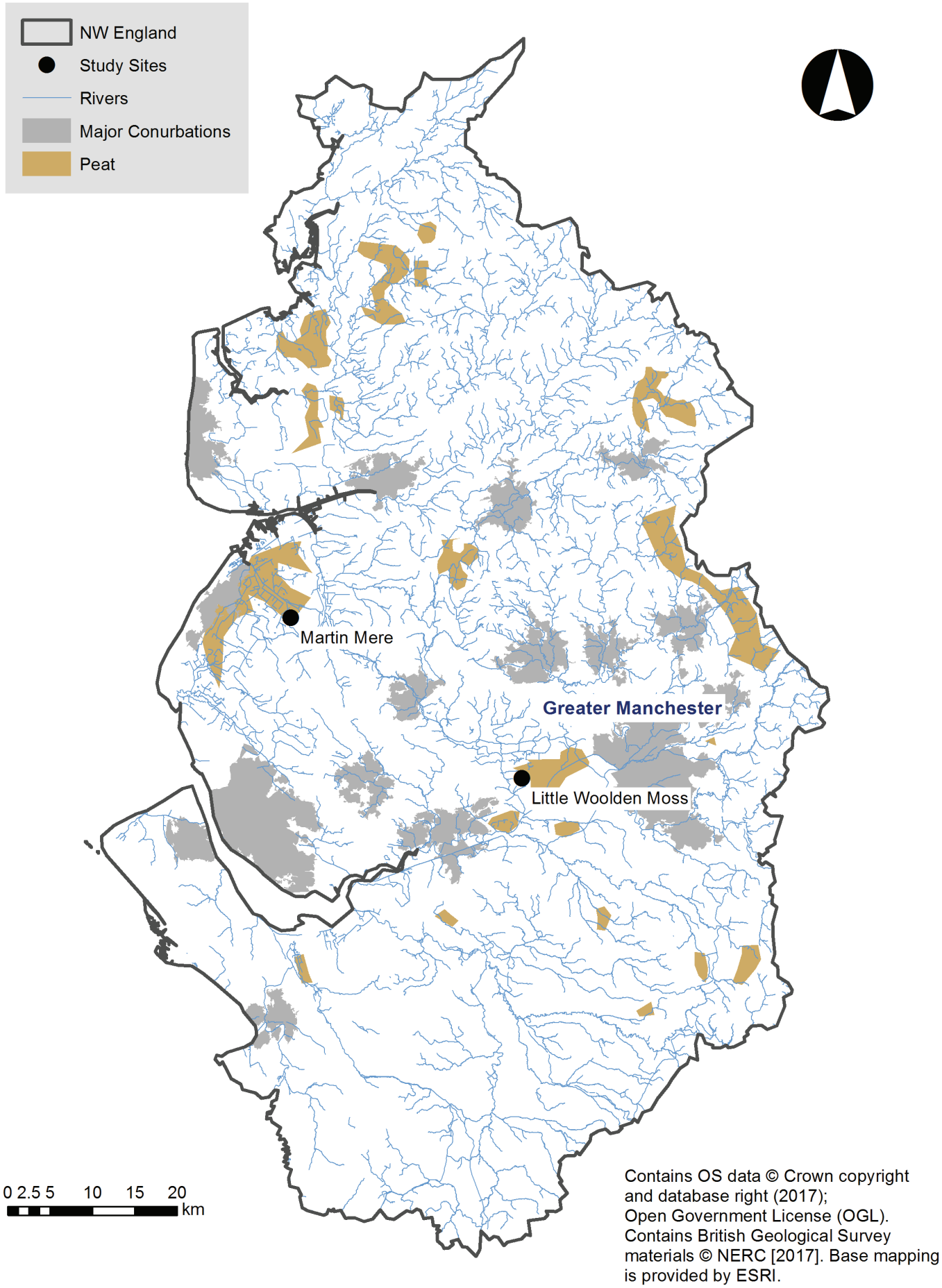


Figure 3: Generalised distribution of peat in north-west England and the locations of Little Woolden Moss and Martin Mere.

Figure 4a: Scrub management at Cadishead Moss; and 4b: Subfossil oak stump at the adjacent Little Woolden Moss. Note that this tree is ex situ, removed from its original growth position, and also that its roots seem to be embedded in the mineral soil that now underlies the peat. Lizzie Bonnar (BSc Hons Geography Sandwich 2016) was a Manchester Metropolitan University student undertaking a conservation placement with Lancashire Wildlife Trust in 2014-2015 (Images October 2014: J. Lageard).

Figure 5a: Vegetation survey of blanket peat at Holme Moss in November 2014; and 5b: Using a Russian corer to retrieve a 0.5m peat core from Holcroft Moss in November 2016 (Images: J. Lageard & S. Caporn).

Figure 6a: Chainsawing a bog oak trunk at Little Woolden Moss, August 2016; 6b: Callum Hayles holding a disc cut from one of the large bog oak trunks; 6c: A dried and sanded bog oak sample ready for ring-width measurement; and 6d: Ring-width measurements being made at the Dendrochronology Laboratory, Manchester Metropolitan University (Images: J Lageard).

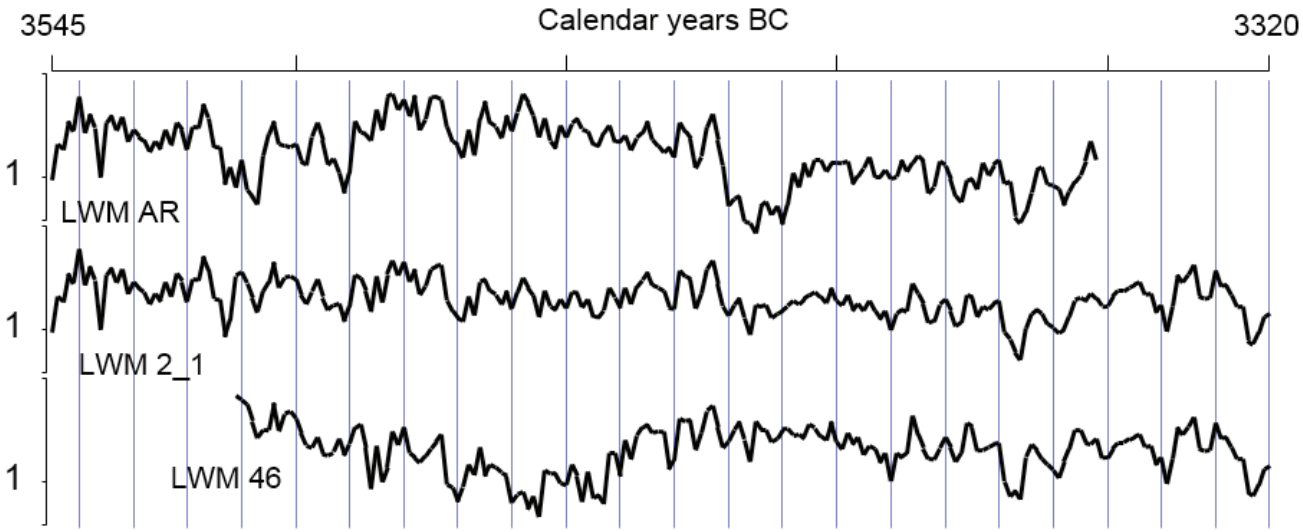


Figure 7: Ring-width curves for bog oak samples LWM AR and LWM 46. These records were combined to create the interim site chronology LWM 2_1 (Data: C. Hayles and D. Brown).

Figure 8: Iris+ (3DR Drone) test flight, Hough End playing fields, June 2016. Images are captured using a GoPro Hero4 digital camera (Image: J. Lageard).

Figure 9: An in situ subfossil oak stump (Quercus spp.) at Little Woolden Moss, unfortunately containing insufficient vertical trunk wood to enable dendrochronological dating (Image: J. Lageard).

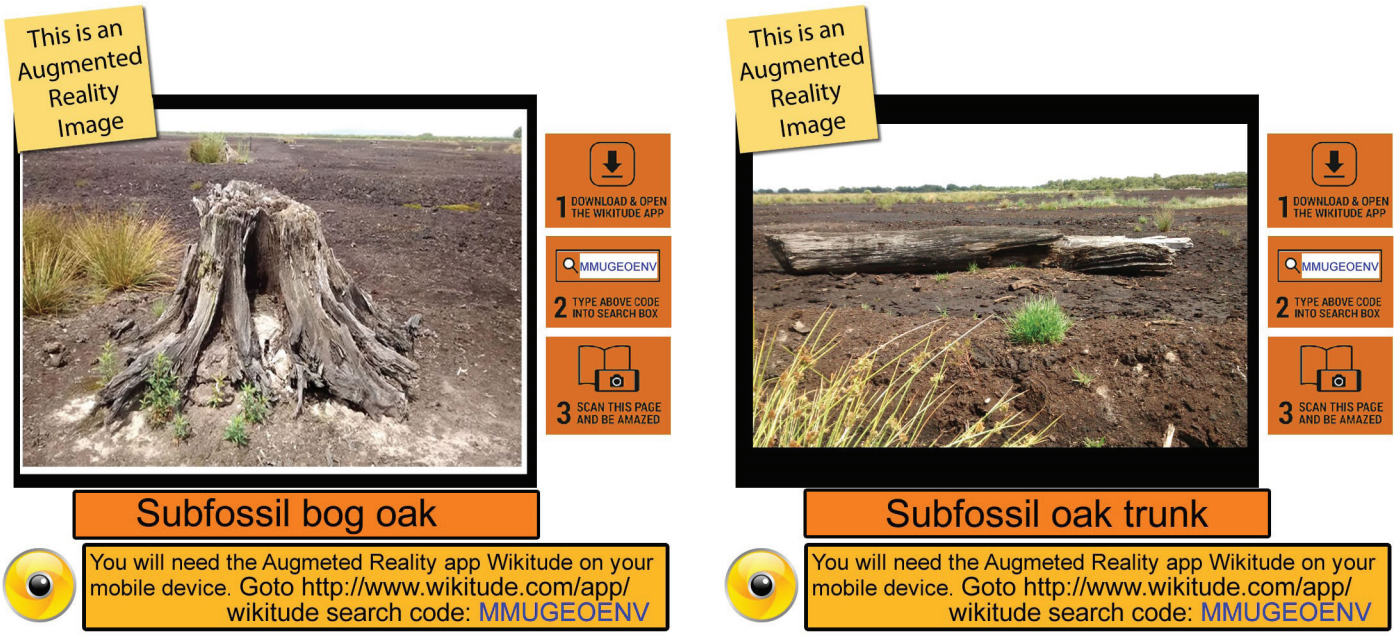


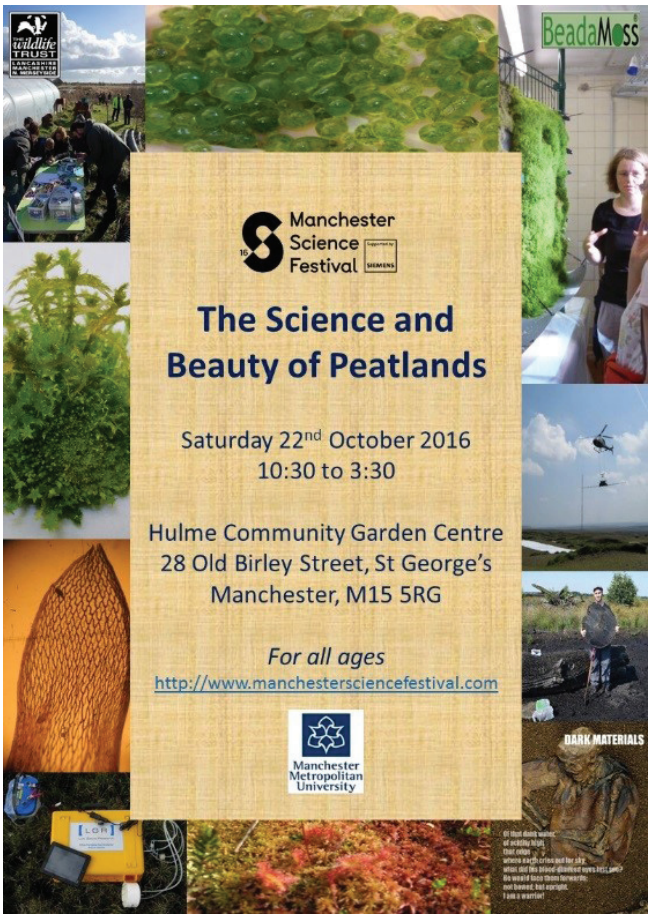
Figure 10: Augmented reality images created for a bog oak stump and trunk from Little Woolden Moss. To view these, even in this paper, download the Wikitude App from the App Store to your smart phone or tablet, enter the code MMUGEOENV and the 3-D image should appear (Images: T. Yip).

Figure 11a: Emma Clarke recording details of a bog oak sampled at Martin Mere in August 2016; and 11b: Pieces of bog oak ornamenting a gravel bank and ditch within the Martin Mere reserve (Images: J. Lageard).

Figure 12: Bags containing samples of five different species of bog moss (Sphagnum spp.). Inset left - 6 Sphagnum spore sacs or sporogonia at the bottom of a centrifuge tube and inset right - measurements of a modern spore of Sphagnum tenellum (Images: T. Briggs).

Figure 13: Anna Keightley measuring carbon dioxide and methane exchange at the bog surface using a Los Gatos greenhouse gas analyser on Cadishead Moss (Images: S. Caporn).

(a)



(b)

Figure 14a: Publicity poster for Manchester Metropolitan's Science and Beauty of Peatlands event held on 22nd October 2016 as part of the Manchester Science Festival; and 14b: Publicity poster for the Chat Moss Bog Oak Festival events, June 2017.

(b)

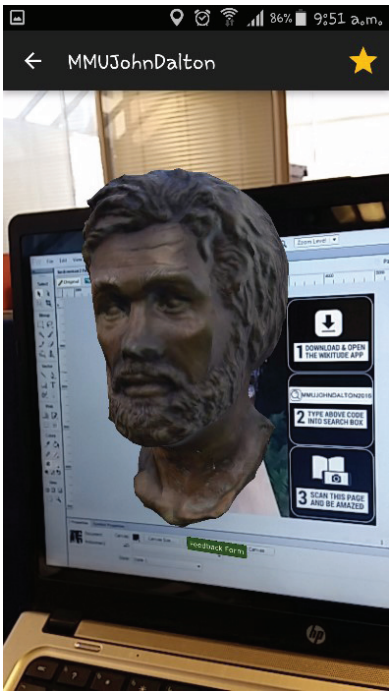


Figure 15a: A reconstruction of Lindow Man's head (courtesy of Professor Stubbs). Careful imaging of this reconstruction from different angles has led to the creation of the augmented reality image illustrated in Figure 15b (© Tor Yip). Follow the instructions in 15a to view the image in AR.

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