Assessing Historical Climate and Fire Regimes in Manacrin Moor, England, using a Palaeoenvironmental Reconstruction

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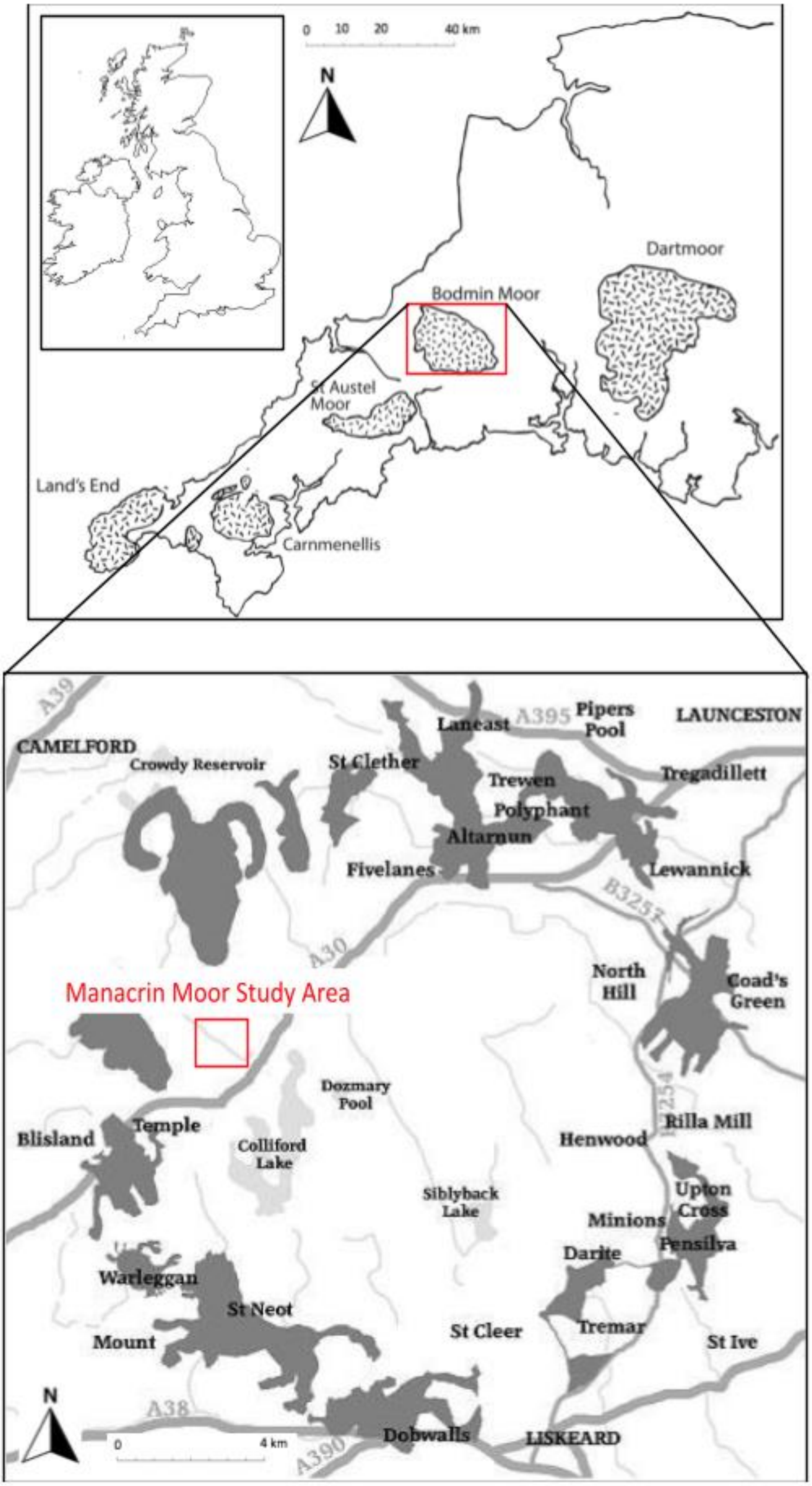
Abstract

Palaeoenvironmental reconstruction is key to understanding how the environment has changed through time; important in predicting and modelling future climatic change. A study into the past climate at Manacrin Moor in Cornwall (England) was conducted through multi-proxy analysis of a 250cm sediment core collected. The study site provides a suitable archive for environmental change as one of the best-preserved landscapes in the UK, through the analysis of testate amoebae, charcoal and loss-on-ignition data. The results from this study were compared to widely researched climatic periods in the Holocene, in order to assess historical climate and fire regimes in Manacrin Moor. They are found to support the three stages of natural climate oscillations observed during the Holocene, and increased charcoal concentrations found ~7000 cal BP can be attributed to increased fire activity in Manacrin Moor. This study therefore outlines the long-term climate variability and past fire regimes of the area, making suggestions for future climate reconstruction research using palaeoenvironmental reconstruction in Manacrin Moor.

1. Introduction

Palaeoenvironmental reconstruction allows for the accurate derivation of past global and regional climatic conditions (Bradley, 1999). It provides significant insight into the reasons for climatic variability which can be influenced by anthropogenic activity and natural external factors such as volcanic activity (Mandel and Holliday, 2017). Analysis of climatic change across the Holocene provides a unique opportunity to do this (Charman *et al*., 2009). The study site, Manacrin Moor is one of the best-preserved landscapes in the UK (Gearey *et al*., 2000a). Comprised from a series of peatlands and lakes across Bodmin Moor, it serves as a palaeoenvironmental archive with numerous high-resolution proxies from across the Holocene (Gearey, 1996). Despite this, minimal research has been undertaken into the area's climatic and fire regime history due to a perceived lack of suitable deposits (Caseldine, 1980). Existing knowledge of the moorland is also primarily based on a previous single pollen profile, indicating poor chronological data for the Holocene period (Gearey *et al*., 2000b).

The study site, located in the centre of Bodmin Moor in north-east Cornwall in the UK [Figure 1], is a 208 km^2 peatland (Brown, 1977). This ombrotrophic peatland receives its moisture from precipitation (Blackford, 2000). Surface conditions in these systems are closely associated with changes in precipitation and evapotranspiration and are therefore particularly responsive to hydroclimate variability (Blackford, 2000). As sensitive indicators of past moisture variation in peatlands, primarily water table depth, testate amoebae (unicellular shelled organisms) analysis is important to this study in deciphering previous climatic conditions during the Holocene (Booth *et al*., 2004) as they live in abundance on the surface of peat bogs. Similarly, charcoal fragments collected in palaeoenvironmental records are resistant to oxidation and microbial activity, therefore reflecting historical climatic variation through the intermediary of vegetation (Mooney and Tinner, 2011). The study area has retained a full sediment sequence dating back to the last glacial period with undisturbed sediments (Brown, 1977), making Manacrin Moor an ideal site for palaeoenvironmental reconstruction as it offers an exceptional opportunity to study past climate during the Holocene. This paper presents and analyses a new sediment core from Manacrin Moor, containing charcoal, testate amoebae and loss-of-ignition (LOI) data in order to reconstruct the historical climate at the site, in order to asses the results against known climatic periods during the Holocene and historical fire regimes. The research thus shows the most important variables needed for reconstructing long-term historical fire data and directions for future palaeoenvironmental reconstruction research.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LAUNCESTON
Tregadillett
Trewen
Polyphant
Altarnun
Fivelanes
Lewannick
B3257
A30
A39
North Hill
Coad's Green
Manacrin Moor Study Area
Dozmary Pool
Blisland
Temple
Colliford Lake
Henwood
Rilla Mill
Siblyback Lake
Upton Cross
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Figure

1. Location map of the study site, Manacrin Moor in central Bodmin Moor, Cornwall, UK. Figure adapted from Rainbow (2018).

2. Methods

A sediment core was collected using a Russian-style corer in January 2020 at the study site, Manacrin Moor. The core collected reached a maximum depth of 250cm and samples of the following were analysed in the laboratory:

Testate Amoebae – 100 testate amoebae were counted per sample, providing raw counts of data; assemblage data was submitted to the most recent European transfer function (Amesbury *et al*., 2016) to produce a palaeohydrological reconstruction of past water-table variability. Testate Amoebae was produced through the peat section of sequence 0-200cm.

Micro-Charcoal – charcoal fragments were analysed and counted through spiking them with a lycopodium tablet (Mooney and Tinner, 2011) containing approximately 10569 spores. They were prepared at regular intervals throughout the core sequence, used to calculate charcoal concentration represented as gram/cm^2 value.

Peat Humification – analysed throughout the sequence between depths of 0-200cm using standard procedures (Chambers *et al*., 2011).

LOI – analysed throughout the sequence between depths of 0-250cm using standard procedures as outlined by Heiri *et al*. (2001).

Software used to systematically produce 'classical' age-depth models, *clam*package (Blaauw, 2010), calibrated ^{14}C and post-bomb dates. Several types of age-models are provided in the software; smooth spline was deemed most suitable for this age-depth model as it limits extrapolation and produced no hiatus', which in comparison, locally weighted spline does not.

3. Results

This section explores the results of the sediment core data collected, converted from raw data counts to percentage or concentration of the sample. Analysis of each sample produced results important to understanding how and why climate has changed in the past and reconstructing this climatic history provides insight into long-term fire dynamics. Standard ^{14}C calibration provides calendar estimates of ^{14}C dates with a mean and ± s.d. error. However non-^{14}C dating information such as nuclear bomb testing in the 1950s, has offered additional dating points for age-depth modelling, increasing the accuracy of the model.

Figure 2 shows the age-depth model and calibration of the ^{14}C date for the study site at Bodmin Moor. The figure represents the age of the sediment core dating back 15000 age cal BP for a depth of 250cm in the sample, indicating an accurate estimate of the age of core depending on its depth.

Producing figures presenting percentage and concentration taxa abundance for samples analysed from the sediment core allows crucial inferences to be reached; percentage taxa of testate amoebae [Figure 3] indicates high percentages of *Archerella flavum*, *Amphitrema wrighianum* and *Trigonopyxis arcula* at 5000 cal BP, coinciding with high humification of ~45% [Figure 4B] and ~99% LOI. A wet and cold climate can be inferred from this, and the importance of hydrology in controlling testate amoebae composition (Bellen *et al*., 2014). However, Figure 3 also conveys contrasting levels of particular testate amoebae data compared to these at the same age cal BP, *Assulina muscorum* and *Euglypha tuberculata*. These taxa, associated with drier water table gradients (Bellen *et al*., 2014), indicate known trends that should be present in such data when analysing water table depth. Charcoal concentration peaks at ~6000 and ~5000 grams/cm^2 at 250 and 3000 cal BP [Figure 4A], remaining high until 7000 cal BP when a steady decrease and constant low is observed in charcoal concentration data. This, along with LOI [Figure 4C] and *Cyclopyxis arcelloides* testate amoebae species decreases simultaneously. This sequence follows a typical hydroseral sequence – lake transition through a fen to become an ombrotrophic peat bog over time (Charman, 2002).

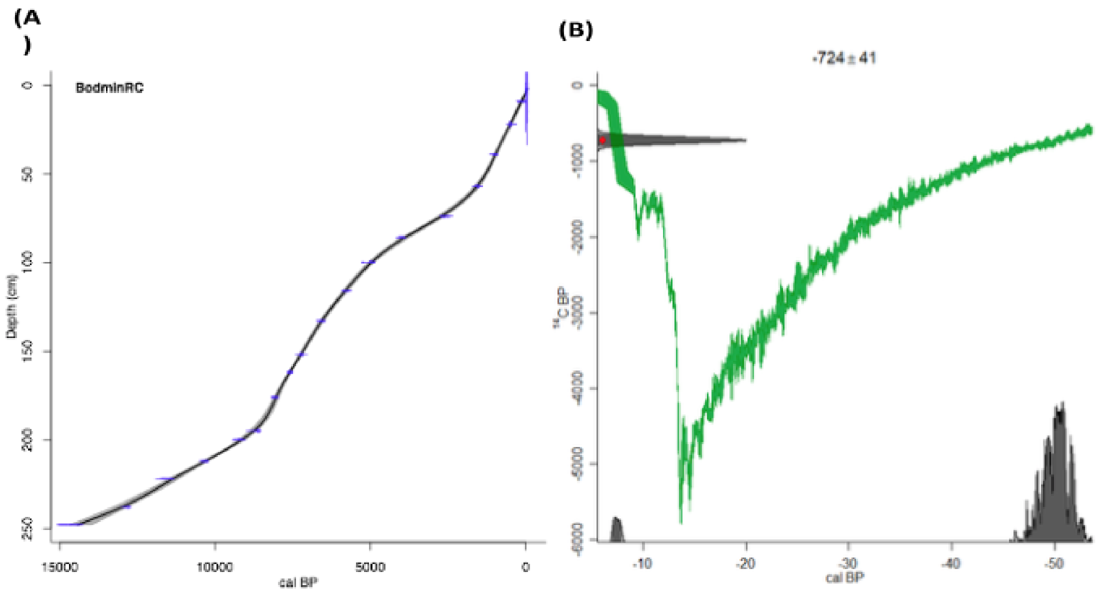

Figure 2. (A) Age-depth model of the sediment record, produced using clam age-depth modelling using a smooth spline (error-weighted with smoothness set at 0.4, showing 95% confidence interval, limited extrapolation and no hiatus

present). (B) Calibration of the ^{14}C date of -724 ± 41 ^{14}C BP at 2 standard deviations.

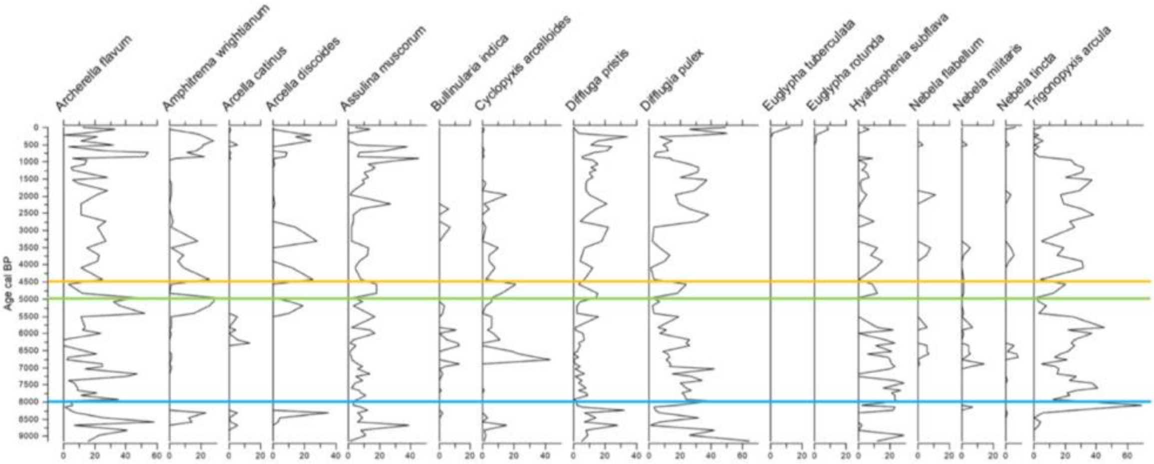

Figure 3. Percentage taxa abundance of testate amoebae in sediment core from Bodmin Moor against age cal BP. The blue line indicates the short-term cold episodes during the Holocene (11,000-8000 cal year BP); the orange line indicates a warm and stable climate (8000-4500 cal year BP); the green line indicates a decreasing temperature trend with high climate instability (last 5000-4500 years).

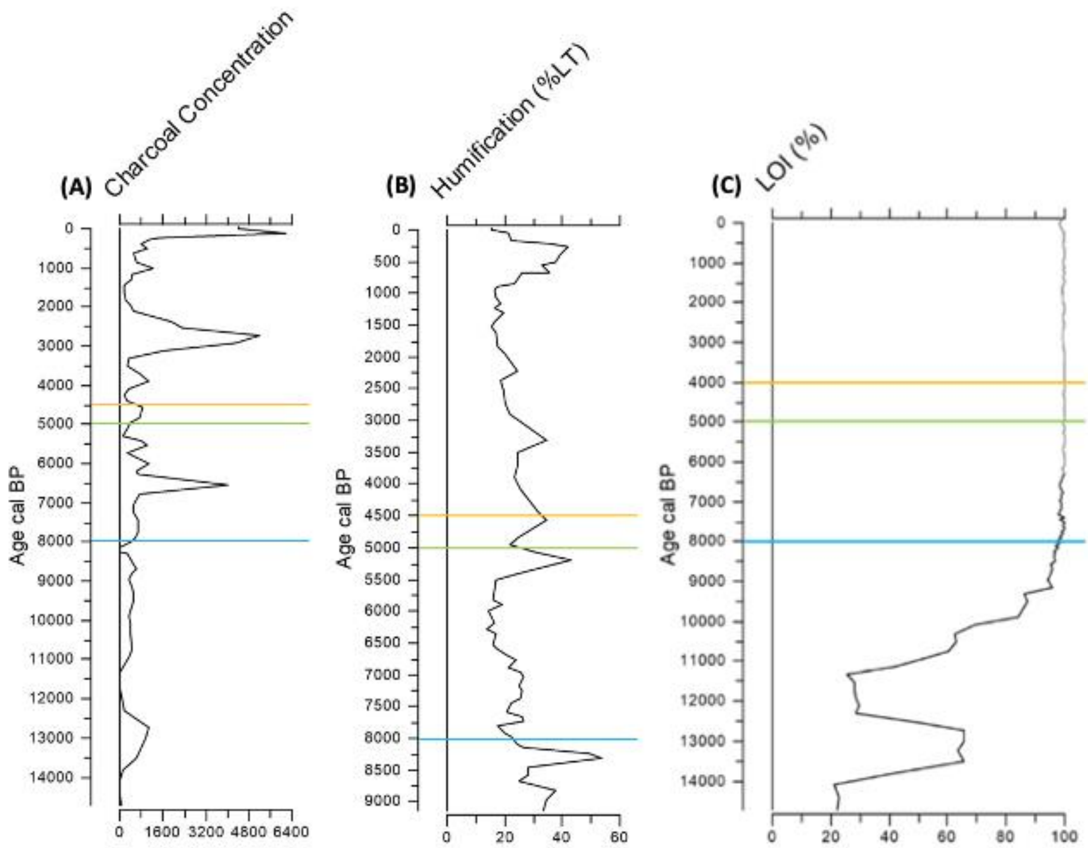

Figure 4: (A) Concentration abundance of charcoal (gram/cm^2) in sediment core from Bodmin Moor against age cal BP. (B) Percentage abundance of peat

humification in sediment core from Bodmin Moor against age cal BP. (C) Percentage abundance of loss-on-ignition (LOI) in sediment core from Bodmin Moor against age cal BP. The blue line indicates the short-term cold episodes during the Holocene (11,000-8000 cal year BP); the orange line indicates a warm and stable climate (8000-4500 cal year BP); the green line indicates a decreasing temperature trend with high climate instability (last 5000-4500 years).

A sharp rise in percentage LOI of 70% is highlighted at 13000 cal BP [Figure 4C], supported by a rise in charcoal concentration to ~800 gram/cm^2 at the same age cal BP, implying another wetter climatic period. However, additional sediment core data at this depth, gained for the other samples would benefit the study, in order to provide further evidence for this climate event and make sound conclusions about the past and make future climate predictions.

4. Discussion

Three stages of natural climate oscillations are observed in during the Holocene (Borzenkova *et al*., 2015); short-term cold episodes related to deglaciation during a stable positive temperature trend (11,000-8000 cal year BP), a warm and stable climate higher than present day (8000-4500 cal year BP) and a decreasing temperature trend with increased climatic instability (last 5000-4500 years).

Results from this study support these known climate events in the Holocene (Borzenkova *et al*., 2015); high percentages of testate amoebae, humification and LOI at 5000 cal BP [Figures 3 and 4] indicate a wet and cold climate at the time. During these periods, temperatures reduced at least 1^{o}C, caused by continental ice sheet melt (Zubakov, 1990). Although the general trend of the Late Holocene cooling is related to summer solar radiation due to natural factors, the causes of these oscillations are still unclear (Borzenkova *et al*., 2015). Moreover, the peak in charcoal concentration along with lower humification percentages at 7000 cal BP [Figure 4B] supports evidence of a warmer and stable climate higher than present day. Therefore, a higher charcoal concentration can be attributed to increased fires in the Bodmin Moor surrounding, resulting in this value. Increased testate amoebae percentage, *Nebela flabellulum* specifically, between 8000-4500 cal year BP further supports a period of warmer, drier climate as the dry indicator species of testate amoebae (Lamarre *et* al., 2013; De Vleeschouwer *et* al., 2009) present imply a lower water table depth.

The results of sediment core data from Manacrin Moor show sound agreement between past climatic events and their percentages or concentrations. Utilising these results allows for historical fire trends to be analysed; charcoal is well preserved in ombrotrophic peatlands and large (<50µm length) particles are understood to be primarily local in origin (Birks, 1997). The samples analysed in this study, <100μm, consequently convey the origin and trend in fire pattern at Manacrin Moor; patterns of fires can therefore be observed during this warm period in the Holocene, reducing in number as the colder, wetter period begins, shown by an increase in water-table depth through testate amoebae [Figure 2]. Association of anthropogenic activity could be evidence for increased charcoal evidence found in Manacrin Moor, as George (2013) concludes Cornwall is an important location for settlements, and burning important for their agriculture. The quantification of charcoal has provided information on past fire activity within a spatial scale that depends mainly on the intensity and severity of fire and size of deposit studied. Moreover, multiple studies demonstrate that the presence of larger pieces of charcoal is a robust indicator of local fire events, and the absence of charcoal is an indicator for the absence of fire. Similarly, testate amoebae, such as *Assulina muscorum* and *Euglypha tuberculate* are associated with drier climate conditions, and *Archerella flavum*, *Amphitrema wrighianum* and *Trigonopyxis arcula* with wetter conditions; therefore, other inferences about past climate can be made, for example water-table depth at the time, depending on the depth of sediment core.

However, the results of this study are also dependent on the reliability of the age-depth model and accuracy of the testate amoebae reconstructions, both of which are associated with some uncertainty (Booth, 2010). The number of samples at the site for proxy-climate comparison is relatively low, therefore calculating correlations based on only a portion of the data is not efficient. Yet by combining data from multiple sites across Bodmin Moor, temporal and spatial changes in proxy-climate correlations over the Holocene can be examined.

5. Conclusions

The outcomes of this study indicate sound agreement between the climate proxies analysed and past Holocene climatic events. They denote a key link between the presence of specific data, for example testate amoebae, and wet and colder or alternatively warm and dry climate periods in time, in addition to other variables, such as water table depth. Moreover, results from the analysis of each sample has aided understanding of how and why climate has changed in the past and reconstructing this climate history to understand long-term fire dynamics; age-depth models also being significant to this. Known climatic periods during the Holocene and results from the study site at Manacrin Moor match, and despite the causes of these climatic events not being certain, they are known to be present.

Additional data looking at multiple sediment core sites in Bodmin Moor in addition to Manacrin Moor, would benefit the study in order to reconstruct past climate and fire regimes in the area, supporting this study in the chosen location. Lastly, contrasting these findings spatially would allow the direct comparison of the impact of anthropogenic factors such as climate change on future climate and fire dynamics at the site.

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7. References

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