Pollen analysis at Loch nan Eala, western Scotland: environmental history during the Neolithic and Bronze Age.

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Mai Wynne Walker

Loch nan Eala (Walker, 2022)

Contents

0.0 Acknowledgements

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1.0 Introduction

This project uses palynological investigations of sediment sequences as a means of reconstructing environmental changes and also potential human impact on landscapes through the Late Neolithic to the Late Bronze Age in the area of the western Scottish Highlands. The site under investigation is the isolation basin, Loch nan Eala, near Arisaig, NW Scotland (Figures 1 and 2).

The research will predominately focus on the use of palynological data combined with the recorded archaeological evidence within the Arisaig area to determine whether there is any evidence for human activity within the landscape. The aim is to add to the important work associated with sea-level change conducted by Shennan *et al.* (1994) and contribute to 'key core' sections of pollen data that has been highlighted for further analysis in previous archaeological investigations (see Carter *et al.,* 2005). Samples taken from a core retrieved from the edge of Loch nan Eala in 1997, stored at Durham University, will be assessed and fossilised ancient pollen identified to produce a data set for further analysis. The core remained untouched in cold storage, making it a perfect candidate for this study. Due to the limitations of fieldwork in the current climates of the Covid19 pandemic making site visits not possible, this core was selected to be used for palaeoenvironmental analysis due to its high organic consistency and likelihood for high pollen retention.

Isolation basins have been widely used in NW Scotland to reconstruct relative sea-level changes since deglaciation (e.g. Shennan *et al.,* 1994, 1995) and can provide valuable data for reconstructing past environments through palynology (e.g. Williams, 1977, Shennan, 1994, 1995, Clarke, 2000, Carter *et al.*, 2005). The impact humans have on the environment can be investigated using pollen biostratigraphy, this is a key tool for analysis of 'invisible' human impact, such as grazing, which is often not visible in excavation. Pollen analysis provides important information on reconstructing past vegetation. This in turn, helps us understand significant changes in the landscape, and how humans and animals may have engaged with it. The use of multidisciplinary practices such as archaeological and palynological investigations can help us build a picture of what it may have been like to live at certain periods of time.

Figure 1 Loch nan Eala panorama, Walker (2022)

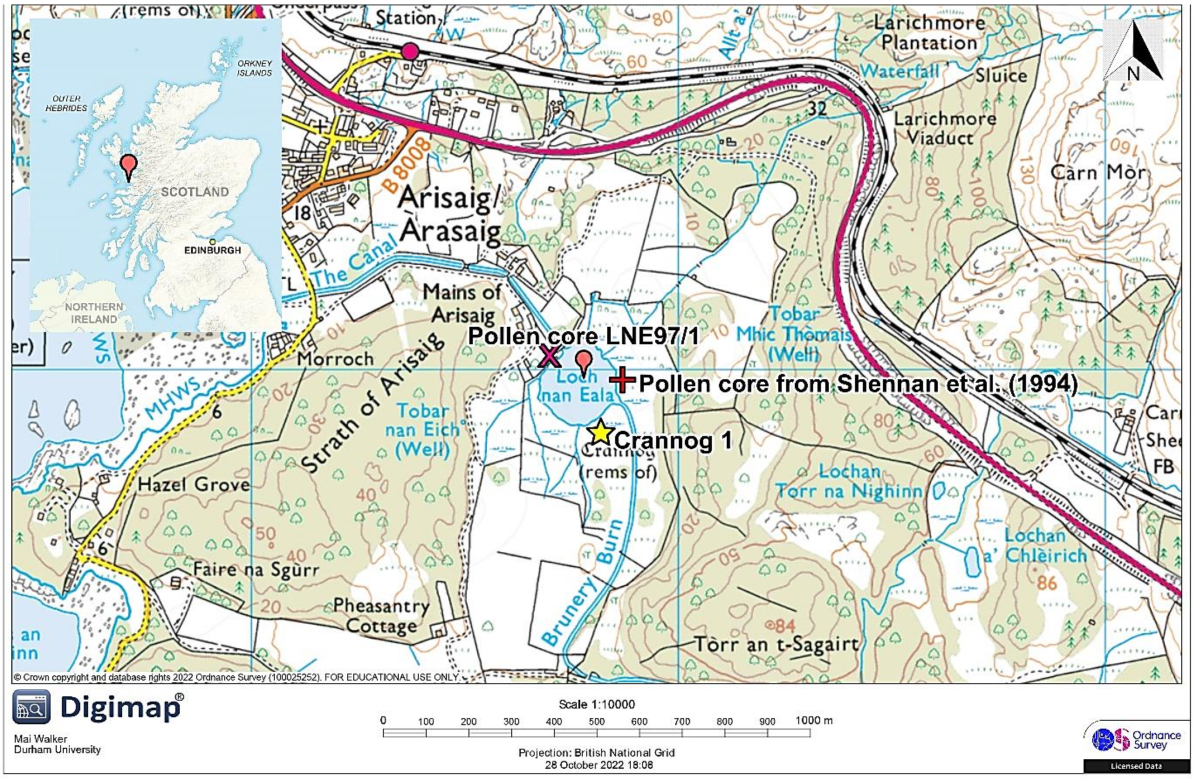


Figure 2 Map with location of Loch nan Eala, Arisaig Red balloon marker indicates the location of Loch nan Eala in maps. X indicates pollen core LNE97/1 used within this study, + indicates location of previous pollen core taken by Shennan et al. (1995) and Star indicates location of Crannog 1 (Created using Digimap, 2022).

1.2 Research Design

1.2.1 Project Rationale

Existing pollen data from Loch nan Eala focused predominately on sea level changes within the loch, predominantly from the early to mid-Holocene (Shennan *et al.*, 1994). This investigation concentrated on the periods between 12,450 and 9000 Cal BP, and 9100, 7450, 4470, 4090, 3880 and 3680 Cal BP (Shennan *et al*, 1994). As a result, the current pollen model for Loch nan Eala has limited constraint and no data from the latter periods, overlooking the most active periods of human activity within Arisaig (Carter *et* al., 2005). Loch nan Eala itself is located within an area of sparce archaeological investigation, the site has a known crannog on the loch edge (Figure 3), alongside a possible second crannog (Figure 9), which was previously recorded as an unfinished log raft (Highland Regional Council, 1986). High resolution pollen analysis of the core will lead to improved understanding of the palaeoenvironment of Loch nan Eala in relation to Arisaig, alongside contributing to the archaeological history of the area. The history of human impact at Arisaig remains debated, particularly within aspects such as woodland decline and increases in arable and moorland (Carter *et al.*, 2005, Clarke, 2000, Shennan *et al.,* 1994, 1995, Williams, 1977*).* Additional environmental data for the Arisaig region can contribute to this debate providing detailed information on changes in vegetation within smaller periods of time.

Carter *et al*. (2005), coupled with previous work by Shennan *et al*. (1994), suggest Loch nan Eala lies within an area of dominant arable land in the later prehistoric periods roughly 5500 Cal BP to 1450 Cal BP. Changes in vegetation, coupled with archaeological sites such as the Crannog lying within Loch nan Eala suggests that during the Neolithic to the Bronze Age there may have been increased human impact within the landscape (Carter *et al*. 2005, Tipping, 2015). The study itself has been the perfect chance to provide an in-depth report on the environmental changes happening during this period of localised and heightened human activity seen from various archaeological sites found in the Arisaig area (Carter *et al*., 2005) (see Tables 1 and 2). The core may reveal important conclusions about the landscape at Loch nan Eala in comparison to its surrounding areas. The sediment core recovered from Loch nan Eala provides an excellent opportunity to address this through high resolution pollen analysis to investigate changes in the landscape associated with human activity (e.g., woodland clearance for grazing/agriculture).

Figure 3 Aerial photograph of Loch nan Eala, with Crannog 1 highlighted in red (Digimap, 2022)

1.2.2 Research aims and objectives

The aim of this research is to investigate the pollen sequence from the late Holocene period to provide new information on vegetational changes from the Arisaig region and determine whether any signs of anthropogenic activities are present at Loch nan Eala. The palaeoenvironmental evidence produced from palynological analysis will be compared to the Shennan *et* al (1994) model, alongside the records produced by (Williams, 1977, Shennan *et al., 1995,* Clarke, 2000, Carter *et al.*, 2005*)* of environmental changes in this region. Additional environmental data will result in a greater understanding of the natural and anthropogenic changes occurring over time.

In order to achieve the aims of this study, the following objectives are addressed:

1. Produce a high-resolution pollen record at 1cm depth intervals, counting a minimum of 300 Total Land Pollen per sample, recording NPP data and microscopic charcoal present within the core.
2. Using the new and existing palaeoenvironmental data, assess the evidence of vegetational changes and whether they may be associated with human impact at Loch nan Eala.
3. Determine if there is evidence in the pollen record which may relate to the Crannogs recorded at Loch nan Eala, and whether the pollen data may contribute any information to the archaeological record.

1.3 Thesis outline

The following chapters present the sequence of progression through the research. Chapter 2 reviews the literature concerning the reconstruction of the landscape through palynological and archaeological evidence within Arisaig and the surrounding areas, as well as the use of sea-level changes provided by Shennan *et al*. (1994) to predict animal and anthropogenic impact likelihood. Chapter 3 outlines the geomorphology and geology of Arisaig and surrounding areas, and also presents the site location investigated and sampled for this research. Chapter 4 introduces the laboratory methodology employed to reconstruct the palaeoenvironment at each site. Chapter 5 outlines the results of these reconstructions through data and graph presentation. Chapter 6 presents the palynological data generated from the site and discusses how this contributes to understanding the regional vegetational changes and potential human impact on Loch nan Eala.

2.0 Literature review

The literature review for this research will be split into two topics that relate to the aims being addressed: the palynological record at Loch nan Eala and the potential impact of human occupation on the landscape at this site and in the Arisaig region.

The environmental background will assess the pollen data available from the surrounding areas and what patterns can we learn from this, while the archaeological background will provide insight into what prior work has been conducted here and how much do we understand the history of this area.

2.1 Palynology and related studies

Palynology is the principal tool used in reconstructing former past flora, vegetation and environments (Faegri *et al*., 1989). The study of pollen is thought to have first started in 1916, when Lennart von Post presented the first modern pollen diagram (Manten, 1967). It has often been used in showing succession of vegetation since the last glaciation and intensification of human pressures upon global vegetation (Moore *et al*., 1994), as well as contribute to aspects of sea level changes as seen at Loch nan Eala in the work by Shennan et al. (1994, 1995).

Moore *et al.* (1991) have suggested that representation of different species of vegetation relies on the visibility of the pollen within the palynological record. It is important to understand the differential factors that may influence pollen analyses. Resistance to decay differs in different types of pollen meaning a lack of survival will impact their representation within the pollen record (Hesse *et al.,* 1999). Modes of transport of pollen also provides a factor of consideration when interpreting pollen data, some pollen, such as *Pinus*, can travel over large distances, providing a more regional signal compared to pollen grains deposited close to a given site (Sofiev *et al.,* 2013). The amount of pollen production of different species widely varies, studies by Erdtman (1969) provides an index of relative pollen production illustrating the dramatic differences in pollen grains per anther, flower or catkin. Differences in pollen production and poor dispersal efficiency within a species can have a drastic impact in what is seen in the pollen record, and may result in the underrepresentation of a species (Proctor and Lambert, 1961). Tauber (1967) discusses the differential results in capture rate of pollen, depending largely on size and on impact with hard surfaces. Larger pollen grains such as *Fagus, Ulmus* and *Tilia* are thought to be caught by obstacles at a much higher percentage than smaller grains such as *Alnus, Betula* and *Corylus* (Tauber, 1967). Other factors such as dampness of surfaces, wind speeds and density of foliage (twigs and leaves), can also cause a higher rate of capture (Chamberlain and Chadwick, 1972).

The use of palaeoecological techniques to determine human influence can be challenging (Edwards and Whittington, 2000, Froyd, 2006, Davies, 2007, Tipping *et al*., 2009, Innes *et al*., 2010, Bishop *et al*., 2015). Agricultural activity is generally the immediate signifier to identify human activity within the area, but few sites provide evidence for cultivation (Davies and Tipping, 2004:234). Behre (1981) argues that Palynological evidence for human activity consists, almost exclusively, of very low or sporadic pollen frequencies of 'anthropogenic indicator' herbs associated with pastoral disturbances. Positive evidence for crop-growing is usually in the form of cereal type pollen representation, as well as grazing pressures through the occurrence of herbs like ribwort plantain *Plantago lanceolata* (Tipping, 1994). Other more ambiguous evidence for woodland clearance/regeneration, is often more debatable in certain types of trends (Tipping, 1994,2002). There have been discussions by Brostrom *et al.* (1998) and Sugita *et al*. (1999) regarding the difficulty of identifying elements such as scale and intensity of land use in palynological identification, as lack of certain pollen does not mean it did not exist, but difficult to prove, such as with cereal pollen (Fossitt, 1996, McCullagh and Tipping, 1998, Smith, 1998, Sugita *et al*., 1999, Davies and Tipping, 2004, Edwards *et al.*, 2005).

Work by Tipping (2002), however, demonstrates the strengths of using pollen analysis, as it provides much more chronologically sound data, providing *in-situ* records of landscape use and even human impact. Pollen data is arguably more reliable than simply assessing many archaeological sites, as cores can provide more accurate ^{14}C dates, rather than the possibility of dating material which was out of situ to original human activity (Tipping, 2002). Although palynological assessment provides important information for human impact, we cannot demonstrate the continuity of occupation around a pollen site, we can only suggest it (Tipping, 2002), therefore a combination of techniques will give a clearer overview of the past. Combining pollen analysis with other proxy methods such as archaeological data and ^{14}C dating (see Bronk Ramsey, 2009) will contribute towards a more complete understanding of landscape changes through time (Tipping, 2002).

Davies and Tipping (2004) present a fairly pessimistic view of identifying small scale human activity using pollen data in the highlands, due to such variations in diverse landscapes of Scotland, it often creates a multitude of problems when attempting to determine anthropogenic indicators. However, when palynology is paired with other methods such as the identification of Non-Pollen Palynomorphs (NPP) and microcharcoal analysis may provide more evidence to help assess impact, rather than isolated anthropogenic indicators such as cereal pollen. Non-pollen Palynomorphs or NPP grains are often counted alongside pollen grains to provide more information to aid in environmental reconstruction, using a standard identification chart (van Geel, B., 2001). Work done by Munk (1957), van Geel (1978), van Geel *et al.* (1983), Davis and Shafer (2006), van Geel and Aptroot (2006), Innes *et al.,* (2010), Cugny *et al*. (2010), Laine *et al.* (2010), Miola (2012) and Baker *et al.* (2013) have demonstrated a variety of ways in which NPP data can be linked to human activity in the landscape, and the importance of their uses in pollen analysis. Recently more emphasis on NPP data from authors such as van Geel (2001) and Innes *et al.* (2014, 2019), has resulted in more interest of the use of NPP's in Palynology. Although, the classification and identification of NPP data in the pollen record is often more difficult due to the limited presence of literature on fossil NPP and NPP studies often being overlooked, with their value often being debated (van Geel and Aptroot, 2006, Cugny *et al.,* 2010). The creation of the NPP-ID; non pollen palynomorph database server (http://non-pollen-palymorphs.uni-goettingen.de), has also allowed for a place where researchers can access relatively up to date photos and information on NPP identification. NPP data can be difficult as an identifier when used without supporting evidence, as many species may relate to multiple causes, for example, the presence of Coprophilous fungal spores (CFS) such as Sporormiella would provide evidence for an obligate dung fungus (van Geel, 1978, van Geel et al., 1983b, van Geel et al., 2003, Baker et al., 2013), however, the presence of Sordaria-type (HdV 55-A) may also be related to dung but can be associated with general decomposition (see van Geel, 1978, van Geel et al., 1983b).

The use of microcharcoal as a marker for intentional burning is also useful for combining with palynology. Blackford (2000) demonstrated that microcharcoal can determine whether an area was burnt or not by the amount present in an extracted core. An uncontrolled burning of heathland in southwest England was examined and microcharcoal counted to determine burnt and unburnt areas, the data showed there were differences in even finely spaced samples. Researchers such as Patterson et al. (1987) Edwards et al. (2005), Dodgshon and Olsson (2006), Froyd (2006), and Grant et al. (2014) have investigated the presence fire events on sites, suggesting a typical burning event will produce a large amount of charcoal when counted in the palynological record. Microcharcoal can cause issues in interpretation as naturally occurring burning events such as wild fires may be mistaken for anthropogenic events such as controlled burning.

2.1.1 Fine Resolution Pollen Analysis

The use of techniques such as fine resolution pollen analysis (FRPA) emerged out of the attempts to link palynology and field ecology (Green and Dolman, 1988). It is a technique which has been widely debated, suggesting that finer resolution analysis in palynology may not provide a result equal to the time inputted for such painstaking labour. However, investigations by Turner (1964, 1965), Moore (1973,1980), Garbett (1981), Sturludottir and Turner (1985), and Scaife (1988) demonstrated resolution at intervals as small as 1 mm, provided positive results which aided in ecological analysis. Innes (1989) provided an in-depth investigation of the application of FRPA, he discussed how FRPA provides a uniquely sensitive technique that addresses problems of prehistoric land-use and ecology that are often overlooked in the pollen record. FRPA has been chosen for this study as it has strong benefits when coupled with other elements such as ^{14}C data, to provide answers to questions of human impact in a very small geographical area during a specified period of time. Further work by Albert and Innes (2015) have demonstrated the use of FRPA on areas with multi-phase proxies to attempt to in investigate less visible period transitions such as ‘rod’ microlith sites during the Mesolithic-Neolithic transition. Although it can be argued that FRPA may not always pick-up small-scale human activities in an area, however, it is important to use techniques such as this when particular research questions are looking at a period of time which humans had lower impact on the environment, such as pre-agriculture, or more rural areas which human activity made be harder to pick up due to a larger overall space.

Green (1983) suggests that interpretation of FRPA data is most advantageous when provided with constant, and fairly rapid, sediment accumulation, advocating varved lake sediments, or the support of an independent chronology. As the project study area is based at Loch nan Eala, a glacial basin loch, it can be thought that sedimentation meets this basis. The use of chronology from Shennan et al (1995) also provides a strong independent chronology which coupled with C14 dates, will provide a good basis for FRPA analysis and interpretation.

Davies and Tipping (2004) argue that small peat bogs may provide more secure diagnostic signal for small scale agriculture than small lakes. Although this can be true in some cases, a combination of techniques and the use of fine resolution analysis, can help combat this issue as a more sensitive and in-depth analysis will help pick up slight changes in vegetation that may be otherwise missed.

2.2 Vegetation history

Vegetation in the British Isles has shifted over time due to varying factors other than human activity, climatic changes leading to periods of warming and cooling (Bond *et al,* 2001*)* (see Figure7), alongside changes in precipitation and rainfall (Charman, 2010) can influence the growth and decline of species. It has been noted by Charman (2010), that there is a significant increase in the number of wet events within northern Britain during the periods 3000 – 2000 Cal BP. As this is the time scale the project focuses on, this information is useful to acknowledge in order to help think about any trends occurring within the pollen data.

Based on pollen analyses from a wide range of locations, woodland regions in Scotland reached their greatest extent 6000 years ago, in the Mid-Holocene Climate Optimum, with densities varying over time (Wilkins, 1984, Bennett and Birks, 1990, Tipping, 1994, Edwards and Whittington, 2003, Oosthoek, 2013, Farrell, 2009). Before agrarian modifications, the dominant woodland in the Western areas of Scotland consisted of mainly *Betula* woodland, with *Alnus* and *Salix* thriving in wetland environments (Tipping, 1994). However, this trend in dominant woodland species does not consider woodland such as *Sorbus, Fraxinus* and *Ilex*, which are more difficult to detect in the pollen record, due to their production of less pollen (Boyd and Dickson, 1987, Tipping, 2003). Figure 4 shows a simplistic account of the vegetation changes occurring in the Arisaig area from the work carried out by Carter *et al*. (2005).

With the varying factors that can contribute to environmental changes discussed above, it is therefore important to take into account that geological, small-scale climatic and topographic contrasts over short distances would have introduced diversity and richness within the major woodland regions (Tipping, 1994, 2003). Techniques such as pollen analysis, NPP comparisons, microcharcoal assessment, ^{14}C analysis, archaeobotanical assessment and archaeological excavation should be used in conjunction, otherwise, as Willis and Bennett (1994), Sugita *et al. (*1997), Halstead (2000) and Davies and Tipping (2004) suggest, palynological reconstructions from large basins can often be insensitive to small scale anthropogenic disturbances. If we are not careful in assessing the data, the levels of human disturbance may be construed as 'natural' activity, and may produce a very sterile profile for the past, missing out the more 'invisible' indicators of human activity.

2.2.1 The nature and timing of human occupation/impact at Loch nan Eala

2.2.2 Previous pollen sites in the Arisaig area

Pollen diagrams are available from five sites in or near to Arisaig and Loch nan Eala: Allt Dail an Dubh-asaidh, Loch nan Eala and Mointeach Mhór in Arisaig, Lochan Doilead in North Morar and Polnish located east of Borrodale (Carter *et al.*, 2005, Clarke, 2000, Shennan *et al.,* 1994, 1995, Williams, 1977) (see Figures 5 and 6). Each hold a fairly complete range of pollen sequences in terms of period of time in which they cover (Carter *et al.*, 2005: 26).

Shennan *et al*. (1994) presented pollen analyses from Loch nan Eala focussing predominately on sea-level changes within the loch (Shennan *et al*, 1994). Although the study provided key palynological information, there was still scope for further assessment, particularly relating to the Late Neolithic and Bronze Age periods of activity which have been flagged by archaeological excavation in the area (Carter, *et al*. 2005). Several studies by Selby (1997, 2004), Selby *et al*., (2000) and Selby and Smith (2006) have provided detailed lithostratigraphical and biostratigraphical studies on the Isle of Skye, data provided by Shennan *et al.,* (1994, 1995, 1996) on Arisaig have also contributed to a greater understanding of the three marine transgressions in the area, since the Late Devensian.

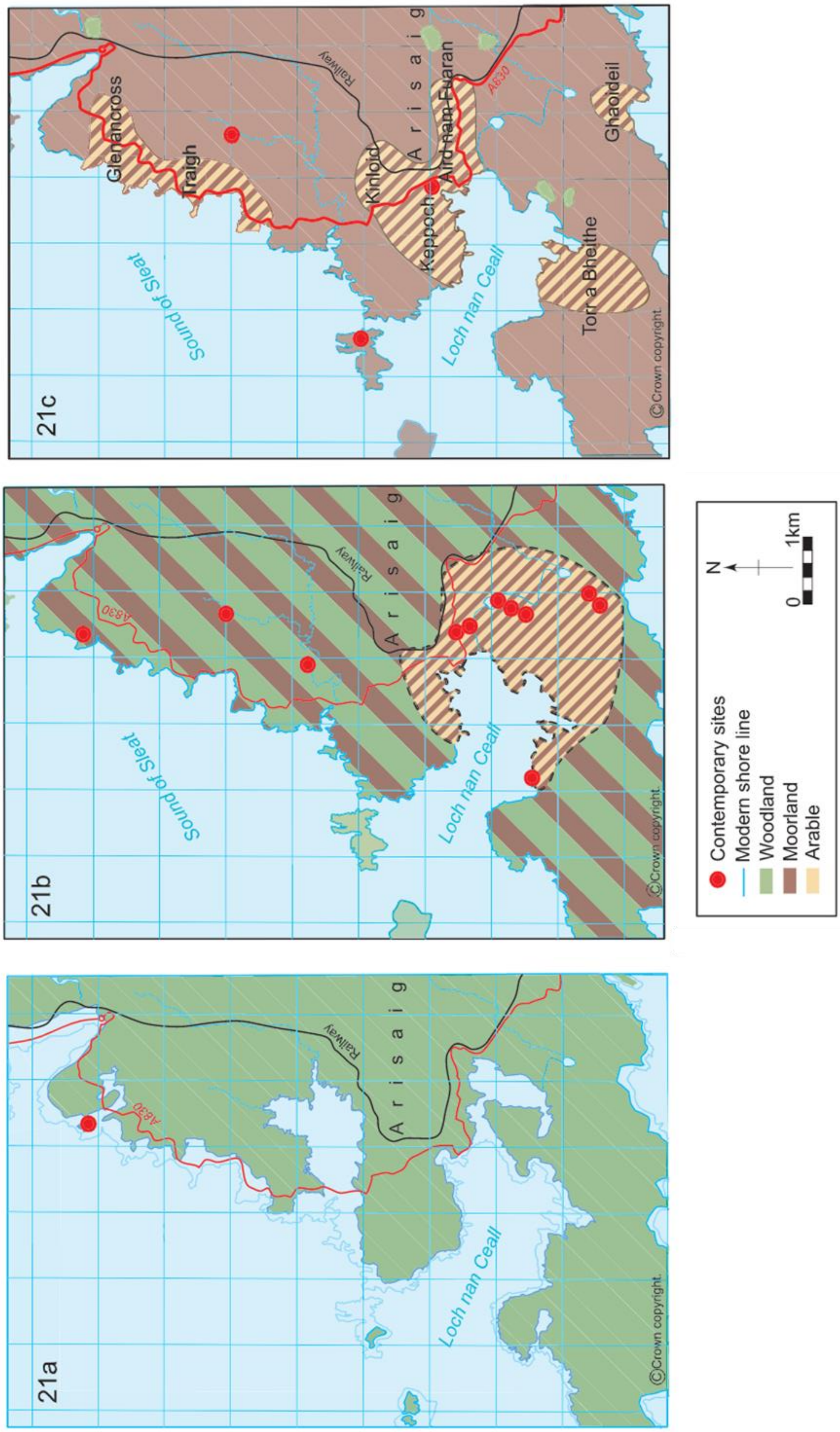


Figure 4 Stages of landscape evolution near Arisaig: (21a) Early prehistory 7500-3550 BC, (21b) later prehistory: 3550 BC to AD 500, (21c) medieval and later period: AD 500-1800 from Carter et al. (2005: 29)

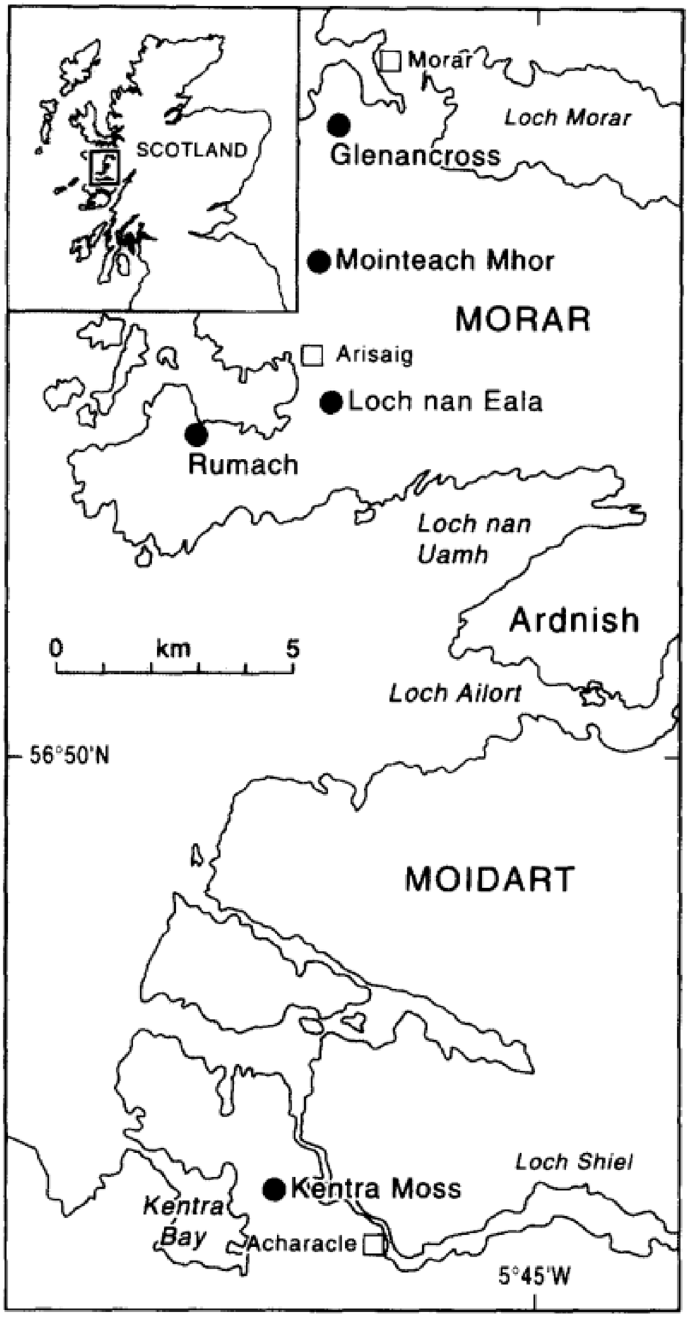
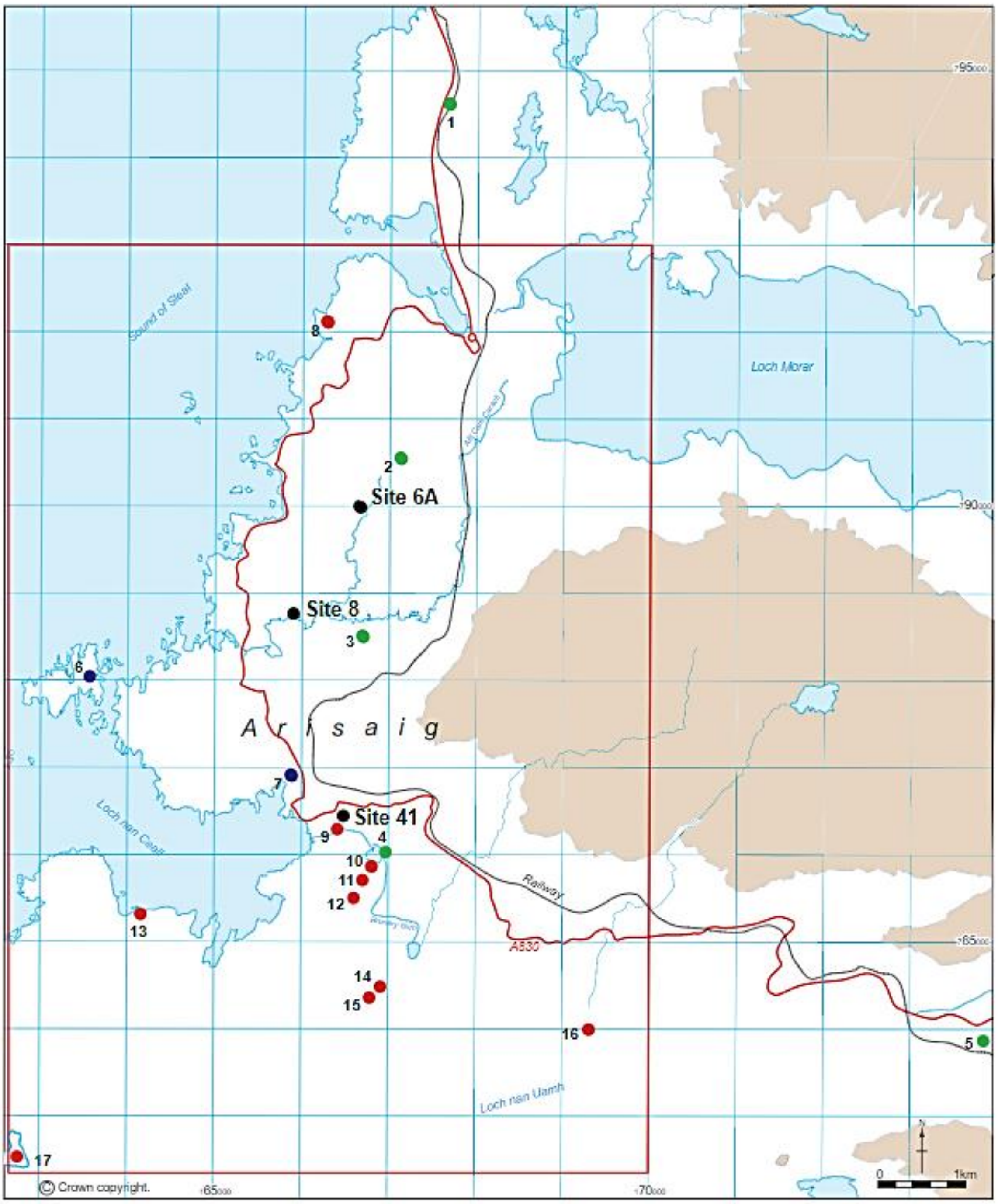


Figure 5 Map of previous pollen sites from Shennan et al. (1995)



KEY

- Pollen site
- Medieval site
- Prehistoric site
- Limit of study
- Land over 200 m

Pollen sites

1: Lochan Doilhead (Williams 1977)
2: Allt Dail an Dubh-asaidh
3: Mointeach Mhor (Shennan et al 1994)
4: Loch nan Eala (Shennan et al 1995)
5: Polnish (Clarke 2000)

Archaeological sites

6: NMRS NM68NW 1: Stronghold and Corn-Drying Kiln. Medieval or later
7: NMRS NM68NE 1.00: Medieval church
8: NMRS NM69SE 1: Mixed scatter. Quartz and flint tools. Mezolithic - Bronze Age
9: NMRS NM68NE 7: Kerbed cairn
10: NMRS NM68NE 2: Crannog
11: NMRS NM68NE 4: Oak platform
12: NMRS NM68NE 6: Cairn
13: NMRS NM68NW 9: Promontory fort
14: NMRS NM68SE 1: Cup-marked stone
15: NMRS NM68SE 5: Cairn
16: NMRS NM68SE 2: Promontory fort
17: NMRS NM68SW 2: Fort

Figure 6 Map of previously recorded Archaeological and Pollen sites in the 6-km section of the A830 road expansion, from Carter et al. (2005)

Carter *et al.* (2005) discuss that from 4500 Cal BP, the pollen record at Allt Dail an Dubh-asaidh (see Figures 6 and 41) includes low but continuous levels of human disturbance, predominantly focusing on small areas of consistent but low disturbance, burning and grazing activity. Much like the record at Loch nan Eala, grazing could be seen in the form of woodland suppression. From 2500 Cal BP onwards at Allt Dail an Dubh-asaidh the vegetation was disturbed on a continuous basis (Carter *et al.*, 2005). These changes may have been, at least partly, caused by broader climate changes (see Figure 7). For example, the relatively cold Bond Cycle event that occurred at 2800 – 2600 Cal BP (see Bond *et* al., 2001) may have also had an impact on the way in which people in the Arisaig area managed the land, as intense cold periods would have caused issues with growth cycles for crops and tree regeneration. The return to a warmer period in 2500 Cal BP, may have allowed the people in the area to begin to exploit the land on a more continuous basis.

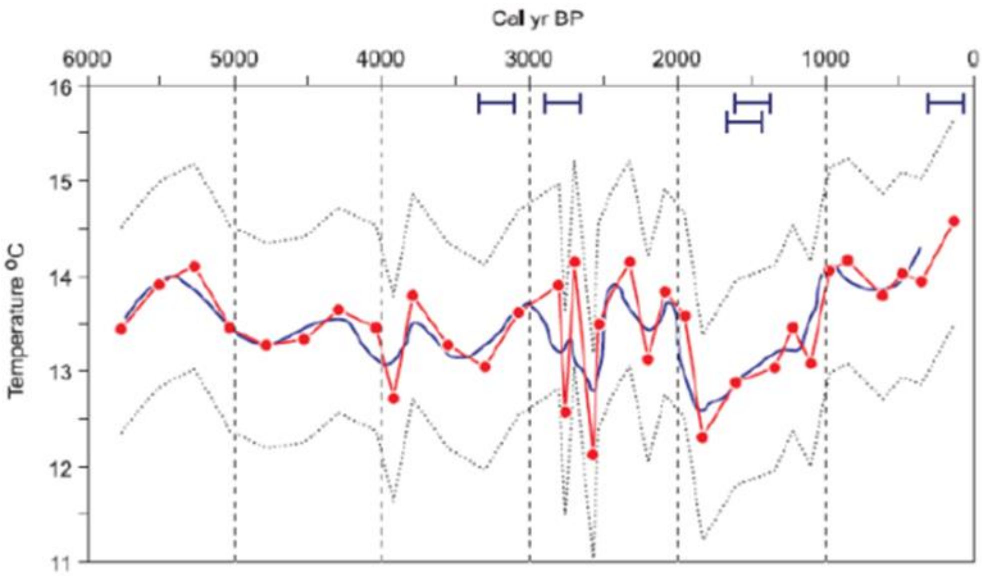


Figure 7 Temperature related proxy records, lake sediment reconstruction based chironomid head capsules, thin red line shows individual data points, thicker black line shows three-point smoothed record. Graph from Langdon et al. (2004).

Strong evidence for vegetation change linked to human activity was found in the Oban from 5750 Cal BP in the Oban area, consisting of a dramatic increase in both the quantity and frequency of cereal-type pollen and an almost continuous presence of light-demanding ruderal plants such as *Plantago lanceolata* (Macklin *et al*., 2000, Bonsall *et al.*, 2002). From 5500 Cal BP it is assumed that the core farming area of Arisaig began to develop (Carter *et al.*, 2005). At this time, it is thought that past peoples were exploiting the limited areas of freely draining raised beach at the head of Loch nan Ceall (Carter *et al.*, 2005). Woodland in the Arisaig landscape remained extensive throughout later prehistory (Carter *et al.*, 2005), with fluctuations in woodland but most dramatically impacted in the Late Bronze Age (see Figure 8), this pattern can also be seen within this study at Loch nan Eala, (also shown by pollen analysis in Shennan *et al*., 1994) and sites in the surrounding areas (Carter *et al.*, 2005).

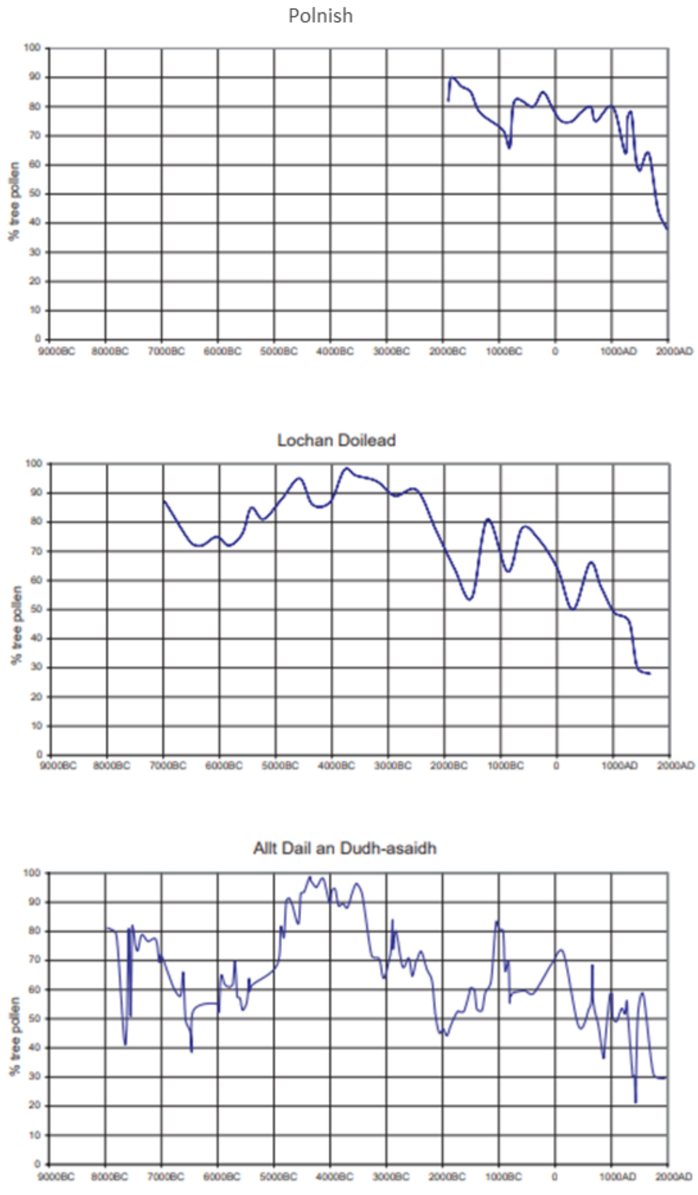


Figure 8 Changes in tree pollen percentages from Polnish, Lochan Doilead and Allt Dail an Dubh-asaidh (Carter et al., 2005)

2.3 Archaeological Background

There have been many studies into the human influence on the landscape within Scotland. Interesting projects that engage with earlier human activities such as Hardy and Wickham-Jones

(2009) have constructed a multiple comprised a survey project to locate and examine sites relating to the earliest, Mesolithic, settlement of the Inner Sound, along the coastlands between Skye and the west coast of Scotland (Hardy and Wickham-Jones, 2009: 1). While Carter *et al.* (2005) have identified landscape changes from the Late Neolithic, through multiple excavations based in the area of Arisaig, where the project focuses on more specifically. Tables 1 and 2 illuminate the archaeological sites that have been databased in the Archaeological Data Service and Canmore as of 2022, Figures 10 and 11 illustrates the locations of these sites in regards to the table of information.

there has been limited attempts to investigate potential human-environment relationships in detail. The Loch nan Eala lies within the potential 'core' settlement area of Arisaig (Carter *et al.*, 2005: 26). Two crannogs found at Loch nan Eala, were reported in 1856 & 1910 (Mapleton, 1870, Blundell, 1911) thought to date from the Iron Age or Early Medieval, and following survey in 1975, were later listed as a scheduled monument in 1985, (HRC, 1986). Recent investigations from Garrow and Srut (2019), however, have shown that crannogs in Scotland may date earlier to the Neolithic period (see Figure 12). The site has not had any further archaeological investigation, leaving a significant gap in dating and understanding for human-landscape interaction at Loch nan Eala. Excavations at Loch nan Eala date back to 1856, meaning the datable evidence cannot be used in such a way, and has since been lost. The signs of a 'dwelling' were noted when the crannog was assessed and excavated (Mapleton, 1870). Remnants of ash, calcified bone, shells of hazel nuts, a small fragment of flint and several angular pieces of white quartz were also found on this level (Mapleton, 1870). It was noted by Mapleton (1870) that the local farmer removed much of the ashes upon discovering it in 1856. The record from Mapleton (1870) discusses the use of Oak and Birch logs in its construction, as well noting that the flagstones lying on top of the logs had strong marks of fire. Although the presence of signs of human activity was discovered at the site, no datable evidence such as pottery was found, carbon dating has not been done to date the crannog itself either unfortunately, making dating near impossible. The illustration of Crannog 2 seen in Figure 9, may suggest that the feature itself may have been a platform or had another purpose, such as a trackway, rather than being a crannog, however, as Mapleton (1870) and the HRC (1986) are the only provider of information, it has been labelled a crannog.

The remains of calcified bones and shells of hazelnut found at Crannog 1 are interesting in relation to what diet may have been eaten at Loch nan Eala, with the site being so close to freshwater and the sea, a wealth of aquatic / marine based foods would be available to the people living there. It is interesting that no mollusc shells or fish bones were recorded at Crannog 1 assemblage, although fish bones are particularly fragile, surviving only where conditions are favourable, and their recovery during excavations depends on the sampling and sieving strategy adopted by the excavators (ScARF, 2022). There is a high chance that the 19th Century excavators would have missed fishbone, however, shell would have been easily spotted. From studies in Scotland and elsewhere, the Bronze Age diet was overwhelmingly terrestrial, with little or no use of marine resources despite the availability to coastal populations (Parker Pearson et al 2019, Curtis and Wilkin, 2019). There has also been a notable lack of marine diet in the Iron Age likely due to beliefs held towards water (Dobney and Ervynck, 2007, Hill, 1995). Other aspects such as temporality, identity, gender, age, status, and location are all factors which may help determine whether a food is perceived to be desirable or appropriate to eat (Caplan, 1997). Therefore, many different 'taboos' on a variety of foodstuffs are likely to be occurring in any given social group, and dietary practices may have differed significantly even within communities (Roberts and Rainsford, 2013). If taboos towards fishing were indeed in place, there would be a greater reliance on animals, fruits and nuts as well as other crops, fostering a cohabitation relationship where in order to have stable resources, humans must manage and maintain the land.

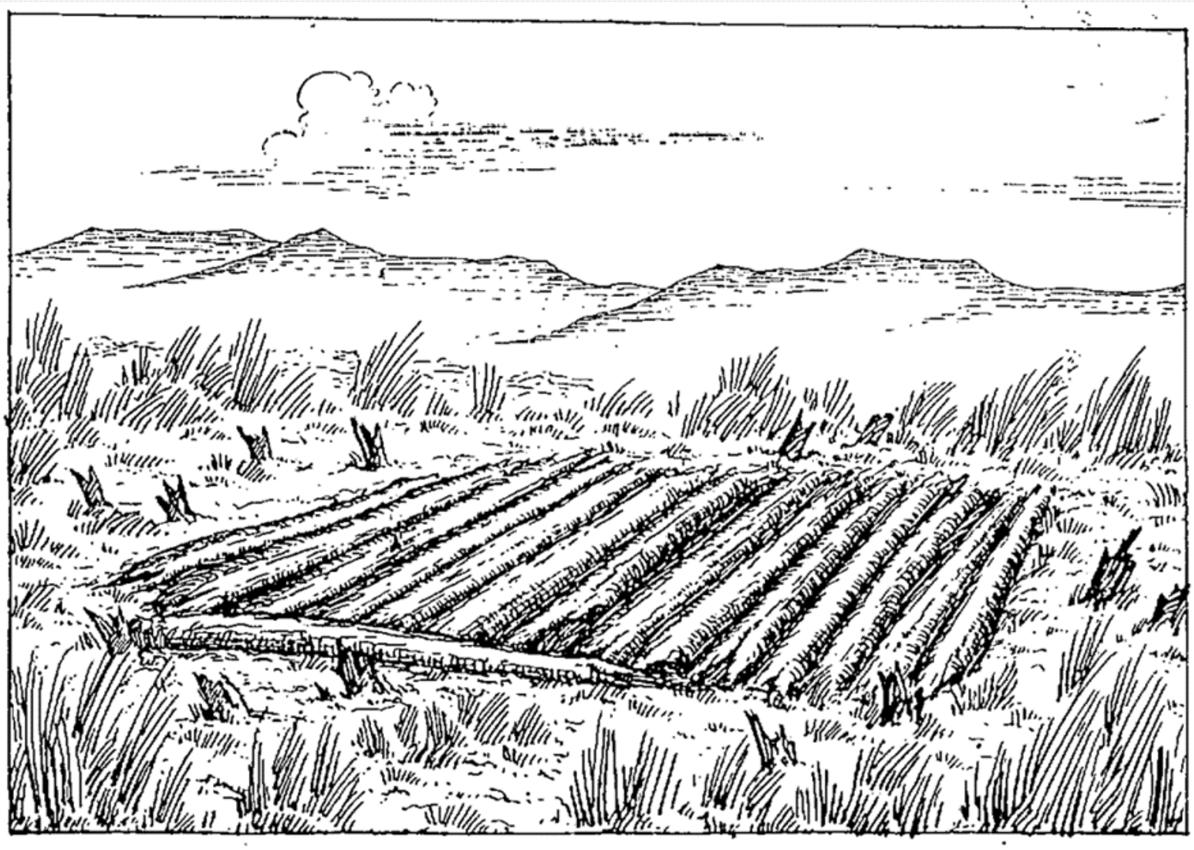


Figure 9 Illustration of Crannog 2 (NM68NE 4) from excavations in 1910-1911 (Blundell, 1911)

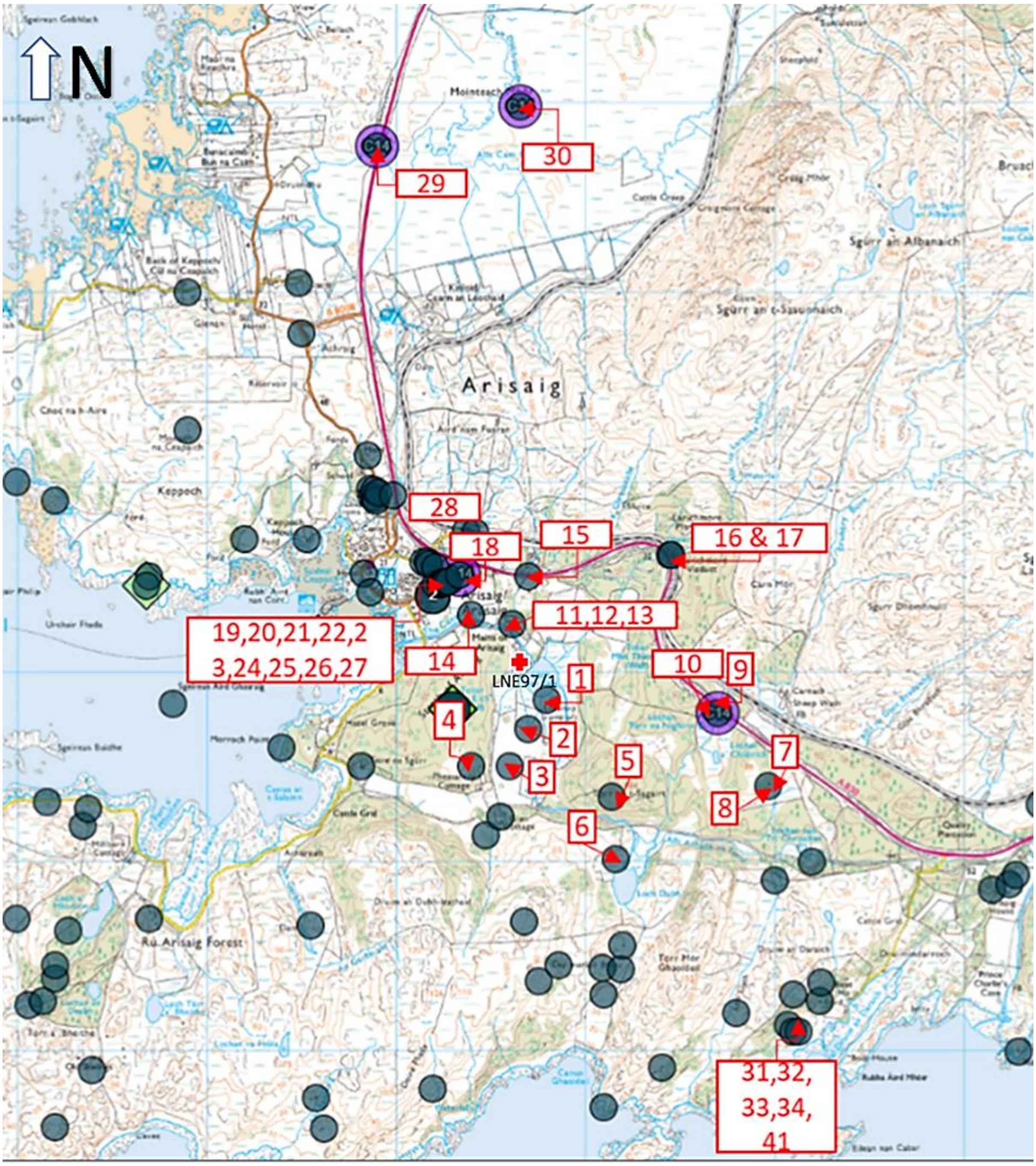


Figure 10 Map of locations of local archaeological sites in Arisaig area, numbers labelled to match sites in Table 1 (created using Canmore, 2022).

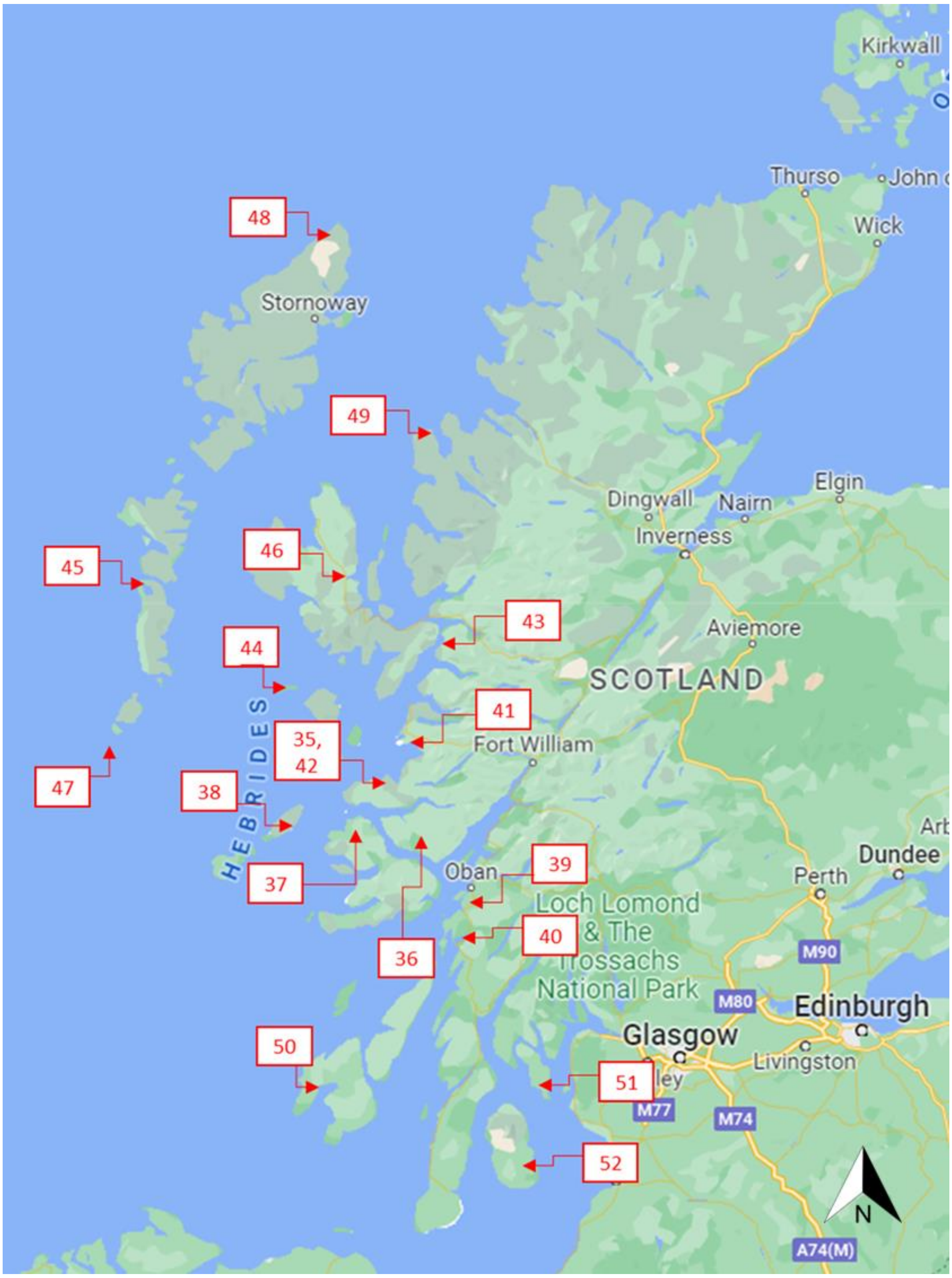


Figure 11 Map of the locations of Prehistoric archaeological sites from Table 2 in Western Scotland (Google maps, 2022).

Table 1 Synthesis table of local archaeological sites close to LNE97/1 core location, with ^{14}C dates, sites which are of similar period to the study area have been highlighted in grey for comparison. For general locations, refer to Map below. (Created using data from Canmore, 2022).

Archaeological site type	Site Name	Location Area	National Grid Reference	Period	14C Material	14C Sample Dates (BC)	Site Reference Link	Map No.
Crannog	Arisaig, Loch Nan Eala 1	Arisaig	NM 6680 8585	N/A	N/A	N/A	http://canmore.org.uk/site/22521	1
Crannog	Arisaig, Loch Nan Eala 2	Arisaig	NM 667 857	N/A	N/A	N/A	http://canmore.org.uk/site/22523	2
Cairn	Arisaig	Arisaig	NM68NE 6	N/A	N/A	N/A	http://canmore.org.uk/site/22525	3
Building	Pheasantry Cottage	Arisaig	NM 664 855	19th Century	N/A	N/A	http://canmore.org.uk/site/232962	4
Field Boundary	Torr An T-sagairt	Arisaig/ Moidart	NM 6714 8534	N/A	N/A	N/A	http://canmore.org.uk/site/232974	5
Naust	Torr An T-sagairt	Arisaig/ Moidart	NM 6716 8501	N/A	N/A	N/A	http://canmore.org.uk/site/133348	6
Building	Lochan A' Chleirich	Arisaig/ Moidart	NM 6797 8540	N/A	N/A	N/A	http://canmore.org.uk/site/233052	7
Rig and Furrow	Lochan A' Chleirich	Arisaig/ Moidart	NM 6797 8540	Medieval	N/A	N/A	http://canmore.org.uk/site/233052	8
Building	Lochan Torr Na Nighinn	Arisaig/ Moidart	NM 6770 8578	Possibly Post Medieval	Peat in area (not diagnostic)	**SUERC-10499:** 8277 BC +/- 45 **SUERC-10500**: 990 BC +/- 35	http://canmore.org.uk/site/233060	9
Farmstead	Lochan Torr Na Nighinn	Arisaig/ Moidart	NM 6770 8578	Possibly Post-medieval	Peat in area (not diagnostic)	**SUERC-10499:** 8277 BC +/- 45 **SUERC-10500**: 990 BC +/- 35	http://canmore.org.uk/site/233060	10
Farmstead	Mains Of Arisaig	Arisaig	NM 66619 86249	Possibly Post-medieval	N/A	N/A	http://canmore.org.uk/site/277550	11
Lade / Canal	Airsaig Canal	Arisaig	NM 66734 86046 to NM 66005 86145	19th Century	N/A	N/A	http://canmore.org.uk/site/277550	12
Saw Mill	Mains Of Arisaig	Arisaig	NM 66619 86249	19th Century	N/A	N/A	http://canmore.org.uk/site/277550	13
Cairn	Mains Of Arisaig	Arisaig	NM 664 863	N/A	N/A	N/A	http://canmore.org.uk/site/22526	14
Burnt Mound	Arisaig	Arisaig	NM 667 865	Possibly Pre-historic	N/A	N/A	http://canmore.org.uk/site/294446	15
Railway Viaduct	Larichmore Viaduct	Arisaig	NM 67457 86612	19th - 20th Century	N/A	N/A	http://canmore.org.uk/site/107588	16

Road / Bridge	Larichmore Road, Bridge Over Bunery Burn	Arisaig/ Moidart	NM 67450 86612	18th Century	N/A	N/A	http://canmore.org.uk/site/108545	17
Kerb cairn / Burial Cairn	Arisaig	Arisaig	NM 6634 8651	Prehistoric	Charcoal, Human bone	**SUERC-2441**: 1420 - 1130 Cal BC **SUERC-2443**: 780 - 1020 Cal AD **SUERC-24444**: 1040 - 1290 Cal AD **SUERC-2445**: 1440 - 1640 Cal AD **SUERC-2446**: 1510 - 1950 Cal AD **SUERC-2450**: 1650 - 1960 Cal AD **SUERC-2451**: 2140 - 1880 Cal BC **SUERC-2452**: 50 Cal BC - 140 Cal AD	http://canmore.org.uk/site/184350	18
Cottage	Arisaig, High Land, 1 New Street	Arisaig	NM 66280 86476	19th Century	N/A	N/A	http://canmore.org.uk/site/108522	19
Cottage	Arisaig, High Land, 2 New Street	Arisaig	NM 66268 86472	19th Century	N/A	N/A	http://canmore.org.uk/site/255354	20
Cottage	Arisaig, High Land, 3 New Street	Arisaig	NM 66269 86474	19th Century	N/A	N/A	http://canmore.org.uk/site/255355	21
Cottage	Arisaig, High Land, 4 New Street	Arisaig	NM 66258 86469	19th Century	N/A	N/A	http://canmore.org.uk/site/255356	22
Cottage	Arisaig, High Land, 5 New Street	Arisaig	NM 66251 86468	19th Century	N/A	N/A	http://canmore.org.uk/site/255357	23
Cottage	Arisaig, High Land, 6 New Street	Arisaig	NM 66246 86467	19th Century	N/A	N/A	http://canmore.org.uk/site/255358	24
Cottage	Arisaig, High Land, 7 New Street	Arisaig	NM 66242 86465	19th Century	N/A	N/A	http://canmore.org.uk/site/255359	25
Cottage	Arisaig, High Land, 8 New Street	Arisaig	NM 66236 86464	19th Century	N/A	N/A	http://canmore.org.uk/site/255360	26

Hall	Arisaig, Astley Hall, The Club Room	Arisaig	NM 66209 86460	19th Century	N/A	N/A	http://canmore.org.uk/site/22524	27
Armorial Panel, Burial Ground, Church, Font, Grave Slab(S), Gravestone	Arisaig, Old Parish Church	Arisaig	NM 65887 86916	16th - 18th Century	N/A	N/A	http://canmore.org.uk/site/22520	28
Structure	Arisaig, Mointeach Mhor	Arisaig	NM 6590 8877	N/A	Charcoal	**AA-41069**: 410 - 200 cal BC	http://canmore.org.uk/site/213882	29
Structure	Arisaig, Mointeach Mhor	Arisaig	NM 6666 8898	N/A	Charcoal	AA-41068: 1410 - 1620 Cal AD	http://canmore.org.uk/site/213880	30
Cairn(S)	Druim An Daraich	Arisaig/ Moidart	NM 68128 84100	Possibly Bronze Age	N/A	N/A	http://canmore.org.uk/site/367873	31
Ring Ditch House(S)	Druim An Daraich	Arisaig/ Moidart	NM 68128 84100	Bronze Age	N/A	N/A	http://canmore.org.uk/site/367873	32
Causeway, Pier, Stone, Structure, Turf Bank,	Druim An Daraich	Arisaig/ Moidart	NM 68128 84100	N/A	N/A	N/A	http://canmore.org.uk/site/367873	33
Cattlefold, Musket Ball(S)	Druim An Daraich	Arisaig/ Moidart	NM 68128 84100	Likely Post-medieval	N/A	N/A	http://canmore.org.uk/site/367873	34

Table 2 Synthesis table of regional Prehistoric archaeological sites with ^{14}C dates, sites which are of similar period to the study area have been highlighted in grey for comparison. For general locations, refer to Maps below. (Created using data from Canmore, 2022).

Archaeological Site Type	Site Name	Location Area	National Grid Reference	Period	14C material	14C Sample Dates(BC)	Site Reference Link	Map number
Occupation site and buried land surface	Ardnamurchan, Gorteneorn	ARDNAMURCHAN	NM626692	Mesolithic	N/A	N/A	http://canmore.org.uk/site/354740	35
Occupation site	Acharn	MORVERN	NM697504	Mesolithic	N/A	N/A	http://canmore.org.uk/site/22481	36
Post hole, Rubbish pit, Hearth, Organic material	Creit Dhu	KILNINIAN AND KILMORE	NM40935318	Mesolithic	N/A	N/A	http://canmore.org.uk/site/312134	37

Lithic Scatter, Animal & Organic remains	Coll, Fiskary Bay	COLL	NM211654 94	Mesolithic	N/A	N/A	http://canmore.org.uk/site/299865	38
Occupation site	Gleann Sheileach, Lon Mor	KILMORE AND KILBRIDE	NM8535 2835	Mesolithic	Charred Hazel nut shell, Charcoal	**AA-8793**: 6390 - 6080 cal BC **AA-17452**: 4370 - 4040 cal BC **AA-17453**: 350 cal BC - cal AD 60 **AA-17454**: 4320 - 3970 cal BC **AA-17455**: 1520 - 1210 cal BC **AA-17456**: 1520 - 1260 cal BC **AA-17457**: 5360 - 5000 cal BC	http://canmore.org.uk/site/22882	39
Cave, Lithics	An Sithean, Kilmelford	KILNINVER AND KILMELFORD	NM840147	Upper Paleolithic	N/A	N/A	http://canmore.org.uk/site/22882	40
Cairn(S), Ring Ditch House(S) Causeway, Pier, Stone, Structure, Turf Bank, Cattlefold, Musket Ball(S)	Druim An Daraich	ARISAIG/ MOIDART	NM68128 84100	Possibly Bronze Age - post-medieval	N/A	N/A	http://canmore.org.uk/site/367873	41
Fort	Dun Mhurchaidh	ARDNAMURCHAN	NM53488 70602	Iron Age	N/A	N/A	http://canmore.org.uk/site/346945	42
Broch	Dun Telve	GLENELG (SKYE AND LOCHALSH)	NG82913 17256	Iron Age	N/A	N/A	http://canmore.org.uk/site/11798	43
Mound, Neo.Pottery	Canna, Beinn Tighe	SMALL ISLES	NG2441 0593	Possibly Neolithic	N/A	N/A	http://canmore.org.uk/site/10716	44

Animal Burial(S), Grave(S), Inhumation, Midden, Structure(S), Wheelhouse	South Uist, Hornish Point, Cnoc Mor	SOUTH UIST	NF 758 470	Iron Age	Charred grain, Shell	**GU-2549**: 350 cal BC - cal AD 30 **GU-2550**: 390 cal BC - cal AD 0 **GU-2020**: 360 cal BC - 60 AD **GU-2028**: cal AD 0 - 340 **GU-2027**: 150 cal BC - cal AD 220 **GU-2026**: cal AD 80 - 410 **GU-2025**: 40 cal BC - 330 AD **GU-2024**: cal AD 120 - 420 **GU-2023**: 50 cal BC - cal AD 250 **GU-2021**: 50 cal BC - cal AD 250 **GU-2019**: 100 cal BC - cal AD 240 **GU-2018**: 60 cal BC - cal AD 250 **GU-2017**: 60 cal BC - cal AD 240 **GU-2016**: 70 - 390 AD **GU-2015**: cal AD 120 - 420 **GU-2022**: 50 cal BC - 260 cal AD **GU-2161**: 200 cal BC - cal AD 130	http://canmore.org.uk/site/9913	45
Henge, Roundhouse, Pits, LBA pottery	Portree, Home Farm	PORTREE	NG 476 444	Neolithic - Bronze Age	N/A	N/A	http://canmore.org.uk/site/296093	46

Roundhouses, buildings, LIA Pottery	Mingulay, Skipisdale	BARRA	NL555818	Late Iron Age - N/A	N/A	N/A	http://canmore.org.uk/site/21362	47
Broch, Building, IA Pottery	Lewis, Dun Airnistean	BARVAS	NB 4886 6266	Possibly Iron Age	N/A	N/A	http://canmore.org.uk/site/4380	48
Burnt mound	Uamh MhÓr, Cove	GAIRLOCH	NG 8140 9170	Neolithic - Bronze Age	TBA	TBA	http://canmore.org.uk/site/367987	49
Pit Group(S), Post Hole(S), Settlement, Structure, Bracelet (Shale), Lid (Stone), Lithic Implements, Rotary Quern, Unidentified Pottery	Islay, Coultorsay	KILCHOMAN	NR 25900 60700	Neolithic - Bronze Age	N/A	N/A	http://canmore.org.uk/site/354358	50
Ditch(S), Structure, Lithic Implement(S) (Pitchstone)	Bute, Kingarth Quarry	KINGARTH	NS 0955 5605	Possibly Neolithic	N/A	N/A	http://canmore.org.uk/site/212266	51
BA Cemetery, Post Hole(S), Short Cist, Structure, Blade (Flint), Cinerary Urn	Arran, Lamlash, Arran High School	KILBRIDE	NS 023 307	Bronze Age	N/A	N/A	http://canmore.org.uk/site/273891	52
Burnt mound	Uamh MhÓr, Cove	GAIRLOCH	NG 8140 9170	Possibly Neolithic - Bronze Age	N/A	N/A	http://canmore.org.uk/site/367987	53

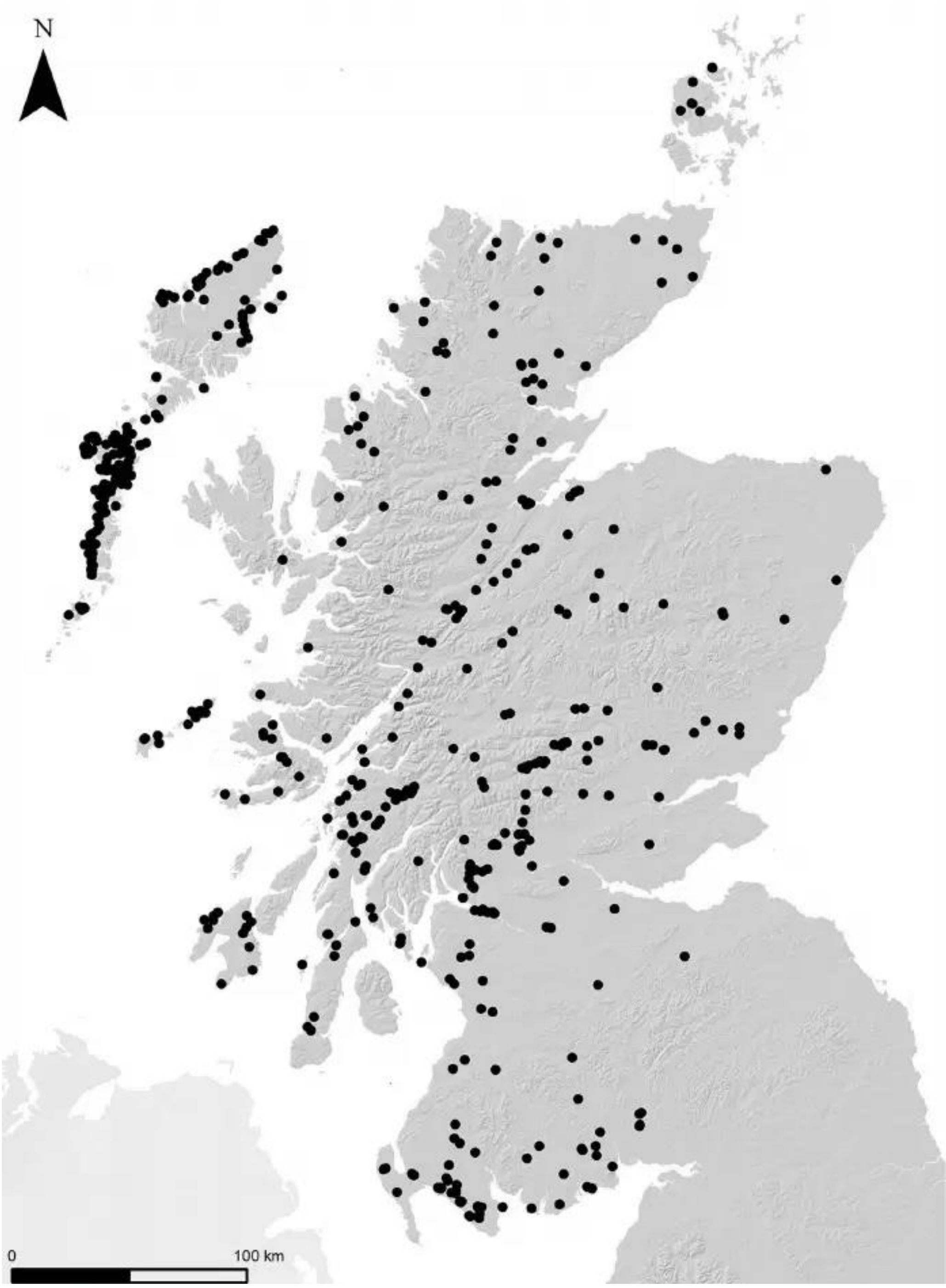


Figure 12 Distribution of island dwellings (including crannogs and island duns) in Scotland (data from Lenfert, 2012) diagram from Garrow and Sturt (2019).

2.3.1 Prehistory of Arisaig

It is argued that humans occupied the west coast of Scotland from approximately 9450 Cal BP (Wickham-Jones, 1990). The Oban region, Argyll, has an archaeological record of human settlement extending back to before 7000 Cal BC (Bonsall *et al*, 2002). However, in the Arisaig region, no identifiable marker of human activity is visible throughout the Mesolithic and early Neolithic periods until approximately 5500 Cal BP (Carter *et al*., 2005). If humans were present during these earlier periods, natural woodlands and resources appear to be exploited without significantly altering them enough to be visible in the archaeological and palynological record (Carter *et al.,* 2005). No apparent evidence has been found for the conventional Mesolithic 'Hunter – gatherer' to Neolithic 'sedentary farmer' transition in Arisaig (Carter *et al.,* 2005). Pastoral farming may have been more favourable than agriculturally exploiting a difficult land, and grazing animals within the woodlands may be responsible for changes recorded in the palynological records (Tipping, 2003, 2004, 2008a, Tipping *et al*., 2007).

Archaeological investigations during the Arisaig A830 road expansion (See Figures 6 and 16) have shown phases of human activity from Early Bronze Age to Post medieval in the Arisaig area (Carter *et al*., 2005, Suddaby and White, 2006). Human activity is detectable from 3550 BC, exploiting limited areas of freely drained raised beach and it is assumed the core farming area of Arisaig began to develop, although direct archaeological evidence is not clear until several hundred years later (Carter *et al*., 2005: 30). The existing archaeological record for Arisaig shows evidence for a localised core area of permanent settlement from approximately the Bronze Age, surrounded by peripheral areas of less intensively exploited land (Carter *et al.*, 2005: 27).

The area of Arisaig is thought to have had little archaeological investigation, information from historic sources has provided some insight into the history of the area, but little excavation was done at the time. The main sources of information have been provided by several road improvement schemes which have conducted both excavation and palaeoenvironmental analysis of the area. Reports from the schemes have provided information on the Arisaig area that contributes to understanding the information being recorded within this research.

Progressive upgrading of the road now known as the A830, was converted from its former single-track status to a modern trunk road was accompanied by archaeological investigations (Rees, 1996). The re-alignment of a 6-km section of the A830 road in Arisaig commissioned several archaeological companies to carry out the work, providing an opportunity to investigate the archaeology of this poorly understood area of the West Highlands (Carter, *et al*., 2005).

Carter, *et al* (2005) and Suddaby and White (2006) provide a detailed report amalgamating the work conducted in the road improvement scheme. The report summarises the history of the area, discussing its lack of attention from archaeologists and antiquarians in the past, contemplating whether it is an absence of interest from researchers or largely due to the lack of substantial archaeology in the area (Carter, *et al,* 2005*)*. A map of sites from road scheme investigations (see Figures 6 and 16) demonstrates how the surrounding area to Loch Nan Eala has approximately 10 prehistoric sites, and 2 medieval sites that have been recorded (see Tables 1 and 2). Sites are concentrated in the vicinity of the present village, with only one site pre-dating the Bronze Age and the medieval period is represented solely by the late medieval church at Kilmory (Carter, *et al,* 2005). Although there was difficulty in dating some features due to many examples of re-use or bioturbation disturbance (Carter, *et al.,* 2005). The report notes that antiquarian interest peaked when a crannog was revealed by the draining of Loch nan Eala, Reginald Mapleton visited the site in 1868 and Odo Blundell in 1911, limited excavations were carried out and not much was known about the site itself (Mapleton, 1870, Blundell, 1911, Carter*, et al.,* 2005).

Investigations were carried out during the A830 road scheme in Arisaig by the Centre for Field Archaeology (CFA) (Suddaby and White, 2006) (see Figure 6), University of Edinburgh and Headland Archaeology Ltd between 2000 and 2001 (Carter, 2005). Excavation and investigation works consisted of multiple phases, Carter *et al*. (2005) focus on particular sites of importance ranging from Sites 3-6: Shieling huts and circular stone features, Site 10: a rectangular turf structure, Site 15: a township, Site 26: a rectangular building, and Site 41: A Kerb cairn – subsequently the closest feature to Loch Nan Ela reported by Carter *et al.* (2005) (see Figures 13, 14, 15 and 16).

6.2.1 Human impact within Arisaig from Archaeological investigation

A small, excavated Early Bronze Age kerb cairn, Site 41, was investigated by Carter *et al.* (2005) (see Figures 13, 14 and 15). Human bone from the central chamber was radiocarbon dated, dating approximately between 4090 to 3860 Cal BP, although later dates were also given from an *Alnus* sample in a later phase of the cairn. A kerb cairn is a type of funerary monument, which is now familiar in the west of Scotland (Lynch & Ritchie 1977), indicating the types of funerary practices of the Early Bronze Age people living in the Arisaig area, although the cairn itself may still have earlier phases with the presence of Beaker pottery predating the Bronze Age (Carter *et al*, 2005). According to Carter *et* al. (2005) there are three other unexcavated cairns in the Arisaig area that may be similar monuments (see Tables 1 and 2). Two of the cairns are similar or slightly larger in size to the excavated cairn, leading to believe they are likely to be similar in purpose, one smaller cairn (NMRS no NM68SE 5) may not be a funerary cairn (Carter *et al*, 2005). Although Canmore (2022) does not appear to have given any dates for these cairns, according to Carter *et al* (2005), it can be presumed that they are of similar date to the Early Bronze Age excavated cairn (see Table 4). If the surrounding cairns are of Bronze Age creation, we are seeing a fairly rich landscape of Bronze Age activity, especially in regard to funerary practices. The existence of the cairns and the activity identified in the environmental records for human impact does show a good correlation, it is likely that the people who were creating these cairns were impacting the landscape in other ways that may not be necessarily appearing in the pollen record.

Figure 13 View of cairn, site 41, after turf removal (Carter et al., 2005).

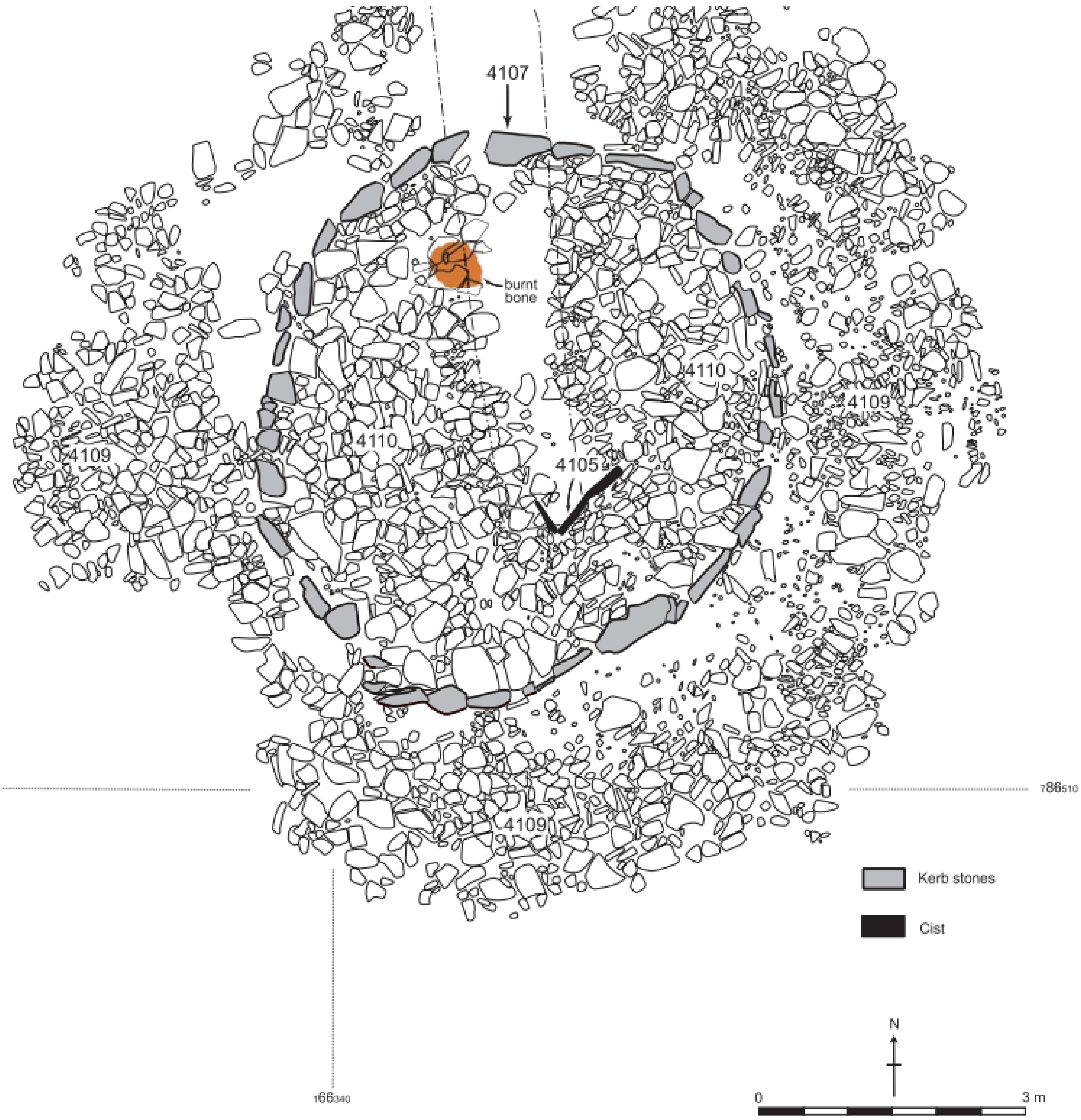


Figure 14 Plan of site 41 / kerb cairn, plan shows outline of kerb and robbed out cist with basal layer of stones, human bone labelled, where ^{14}C dates were taken from (Carter et al., 2005).

Figure 15 Photographic record of Site 41, kerb cairn stones, view from the North (from Carter et al., 2005).

Tipping (2002) suggests that directly using archaeological structures to demonstrate the impact of human activity can often be too simplistic. Looking at Tables 3 and 4, the regional recorded impact of Bronze Age sites appears to be very low in comparison to other periods. Archaeological investigations of the Arisaig area have demonstrated that there is frequent reuse of temporary sites from prehistory, in particular the Bronze Age (Carter *et al*, 2005), as demonstrated from carbon dating evidence of Bronze Age sites being reused into the medieval. A small quartz lithic assemblage was found in Site 8 near Mointeach Mhór, from excavations by Carter *et al*, (2005), within likely earlier Bronze Age deposits below Post-medieval structures, the minor Bronze Age deposits had been disturbed by turf cutting. Although Carter *et al*. (2005) mention the presence of cereal grains at some of the excavated sites in Figure 6 and Figure 16, the plant macrofossils such as hulled barley, oat and hazelnut shell fragments that were found within archaeobotanical samples appear to relate to later dates, predominantly medieval. The lack of information regarding archaeobotanical data from the cairn sites is disappointing, as we cannot definitely confirm that they were sites of Bronze Age agriculture, although there is a high chance that a reused site would suggest it may be likely. As Arisaig has a 'core settlement' area which has multiple reuse sites, it is important to combine all investigatory tools as few sites provide evidence for cultivation (Davies and Tipping, 2004).

As we must not confuse human impact with visible archaeological 'sites' (Tipping and Tisdall, 2004), the lack of clear evidence for agriculture such as cereal pollen should not be a direct determining factor for the lack of agricultural practices. Evidence from sites such as Kilbraur, in Sutherland northern Scotland, revealed preserved *Pinus* stumps, dating to the later Neolithic, but showed evidence of Bronze Age tool marks through possible peat cutting activity (Timpany, 2010). Anthropogenic activities such as these are often unseen and the act of peat cutting for fuel may also play a vital part for past peoples in collecting essential resources. Plant macros and other agricultural bi-products are a very useful tool for looking at signs of human activity, but due to the loss of important data and environmental finds at Loch nan Eala, we have no evidence to say if cereal grains may have been cultivated there. The evidence found at the excavation of Crannog 1 in 1856 (see Mapleton, 1870) indicates that there were burnt hazelnut shells present at the site. It was very likely that they were eating Hazelnuts at Loch nan Eala, and gathering the nuts from the extra local flora at the site location. Although we cannot tie an exact date to the Crannogs currently, the practice of foraging transcends time and space, certainly not being limited to the hunter gatherer periods.

Carter *et al.*, (2005) argue that the key human impact in the peripheral areas has been the extensive modification of vegetation and, indirectly, of soils caused by the felling of trees and grazing of livestock. What is being seen in the 'core area' of activity, is the rare occurrence of archaeological sites, but rather vegetational impact and manipulation. The occurrence of archaeological sites such as crannogs and cairns give us only a glimpse of anthropogenic activity and are therefore of little value in gauging the nature and degree of human impact (Carter *et al.*, 2005). No excavated evidence for human activity was found in the peripheral area before the Bronze Age yet sites such as Loch nan Eala, Polnish, Lochan Doilead and Allt Dail an Dubh-asaidh documented progressive removal of woodland in the pollen record from the Late Neolithic period through to the present day without any significant reversals in this process (see Williams, 1977, Shennan, 1994, 1995, Clarke, 2000, Carter *et al.*, 2005).

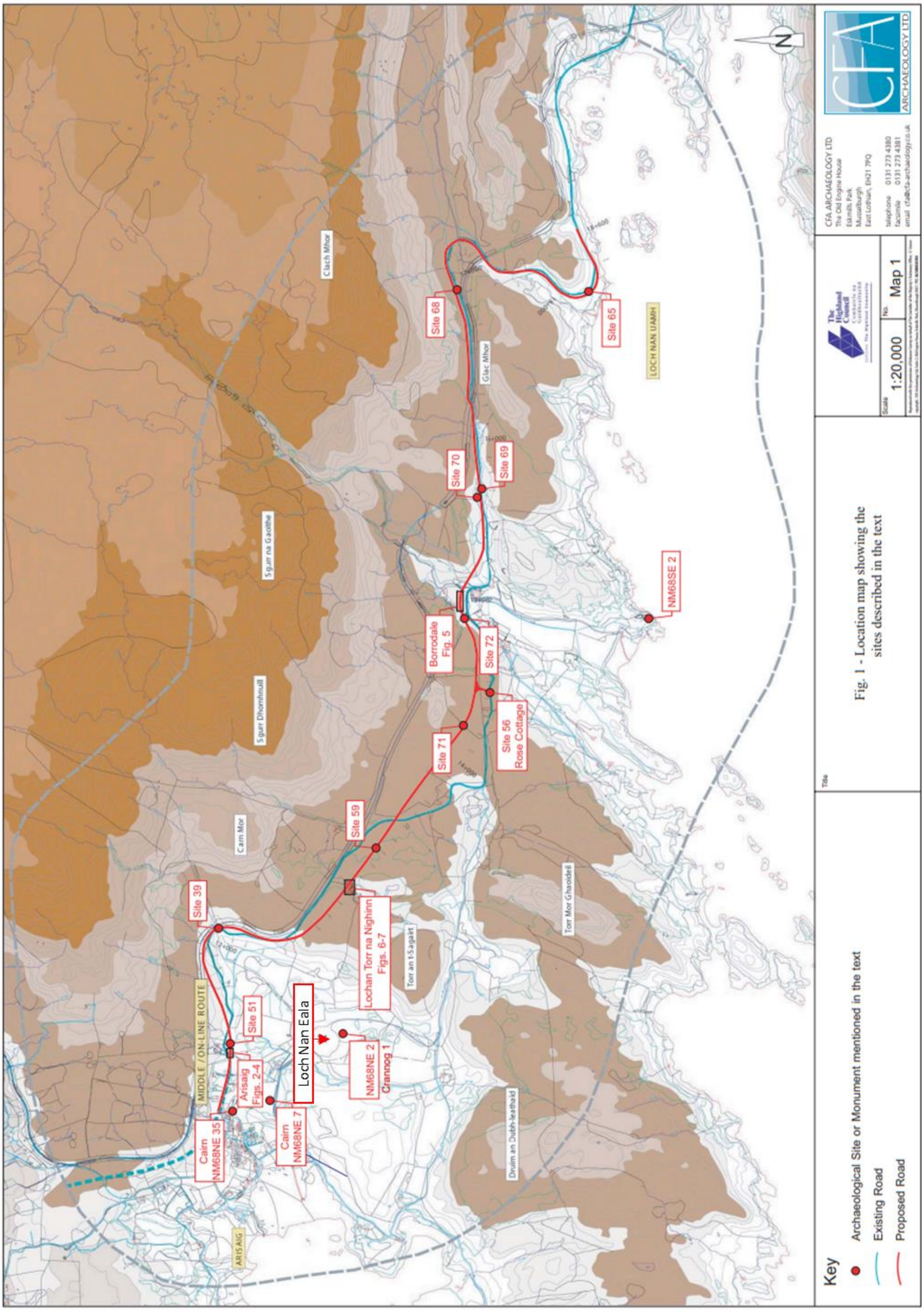


Fig. 1 - Location map showing the sites described in the text

Figure 16 Location map indicating the sites investigated by CFA, with Loch nan Eala and Crannog 1 located, demonstrating surrounding sites (from Suddaby and White, 2006)

2.3.2 Post Medieval

Carter *et al*. (2005) argues that the social and economic upheaval caused by the Highland Clearances, roughly 1780 – 1855 AD (Richards, 1982), can be seen reflected within the abandonment and disrepair of sites within the archaeological record. Carter *et al.* (2005) also argue that evidence of the clearances in the pollen record is not visible leading to the scepticism of pollen as an indicator of events. Whilst evidence for abandonment of buildings during this time can be seen within sites such as Brunary Burn, just east of Loch nan Eala, during the 1840s (white *et al*., 2009), alongside eviction records within historical accounts (White *et al*., 2009) it can be disputed that within Arisaig, movement of people may have been more fluid and returning to the more populated areas on the coastline due to financial unrest and famine occurring at the time. White, *et al*. (2009) also note the vast movement from crofts to grazing pastures and deer hunting areas for the wealthy during the 19th and 20th century. This may suggest the re-establishment of woodland within the landscape, a possible way in which we can indeed see the effect of the clearances in the pollen records, although this event has not been seen within any of the pollen records from previous palynological sites in Arisaig (Carter *et al.,* 2005). A man-made canal (Figures 17, 18 and 19) cut in the 19th century was created to allow water from the loch to be used to drive a mill at Mains farm (Mapleton, 1870, iii). When the mill was closed, water was allowed to run freely to the sea (Mapleton, 1870), meaning the loch remains at a fluid state of water retention (Shennan *et al.,* 1994).

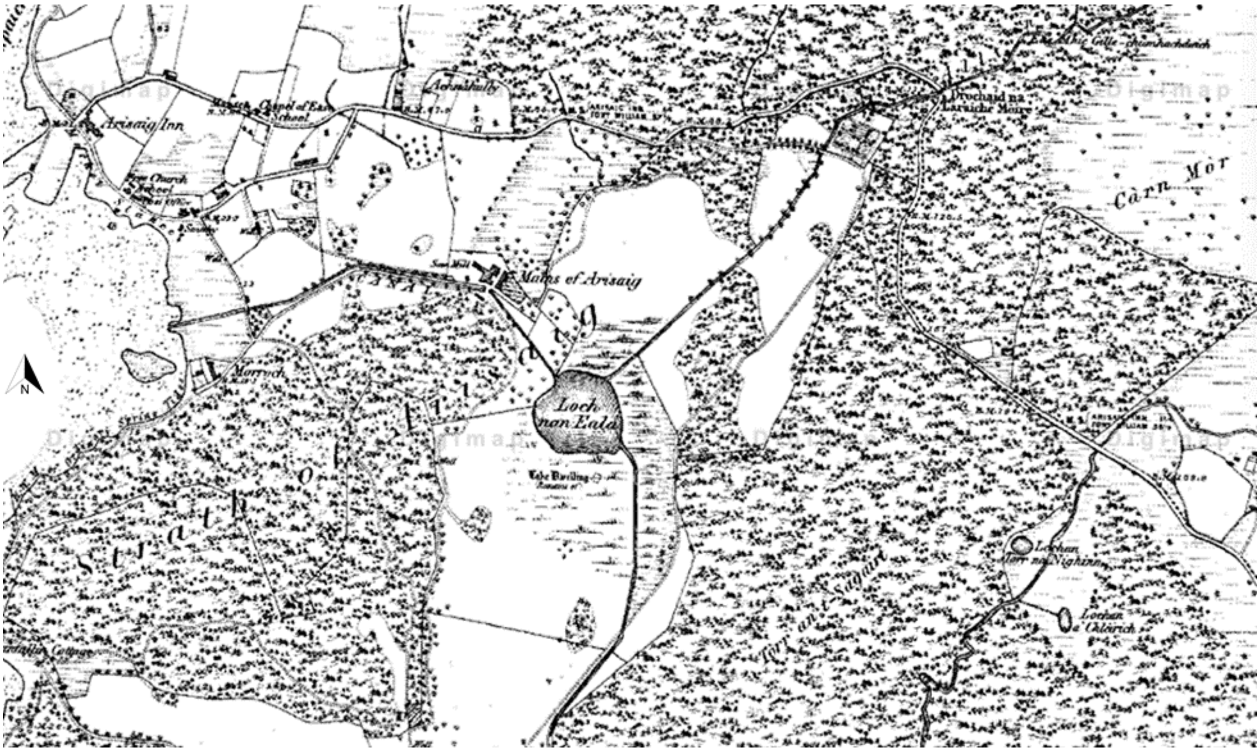


Figure 17 Map of Loch nan Eala from 1900 records (Canmore, 2022)

Figure 18 NW facing photo of remnants of watermill and man-made channel (Walker, 2022)

Figure 19 NNW facing photo of man-made channel interface with Loch Nan Eala (Walker, 2022)

Brunary Burn, located to the East of Loch nan Eala, indicates the building was likely abandoned during the 1840s, but it is unclear if this was forced eviction (White *et al*., 2009: 10). Pastures for sheep grazing became increasingly popular from the 1760s with a gradual to increase from Carter *et al.* (2005), Davies and Tipping (2003), Halstead (2000), Tipping (1994), Sugita *et al*. (1997) and Willis and Bennett (1994) suggest, pollen from farming tends to be very localised and usually not picked up in pollen sites. Events such as the highland clearances, may have been too short an event to pick up within typical pollen analysis depth ranges (Carter *et al*., 2005: 31). Although this period is outside of the research area, it is useful to examine the use of land by humans within Arisaig throughout time.

3.0 Geographical location and typography

Loch nan Eala, 'Lake of Swans', is located at grid reference NM 6676 8597 on the outskirts of Arisaig, see Figures 2. Arisaig is located in the Western Highlands, alongside neighbouring districts of Ardnamurchan, Knoydart, Moidart and Morar, this general area is often referred to as the 'Rough Bounds' (White *et al*., 2009). The 'Rough Bounds', also refers historically to the difficult terrain, and almost impenetrable nature of much of the landscape, as well as the isolation of the population (White *et al*., 2009). Arisaig was covered by the British and Irish Ice Sheet during the Last Glacial

Maximum period (approximately 29,000 – 19,000 BP), it was outside the limits of the Loch Lomond Stadial ice re-advance (12,900 – 11,700 BP) (Bickerdike *et al*., 2018).

Arisaig, is located on a former coastline, consisting of sands and gravels with a Psammite bedrock (See Figure 20). The sheltered anchorage at Arisaig, at the head of Loch nan Ceall, is provided by the rocky headlands of Keppoch and the Ru Peninsula and by low rock islands. Loch nan Eala consists of several complex isolation basins which occupy an area of low-lying land behind the Strath of Arisaig, at the eastern end of Loch nan Ceall, the core was taken from the main basin (Figure 27) (Shennan *et al.*, 1994, 1995). At Arisaig, Shennan *et al*. (1993, 1994, 1995, 1996) record a falling relative sea level from c. +21 mOD at 12040 ± 110 Cal BP to +5.20 ± 0.50 mOD at 10060 ± 86 Cal BP, Selby *et al*. (2000) indicate that land uplift continued to be greater in comparison to sites located in Skye at Inver Aulavaig, through the Windermere interstadial.

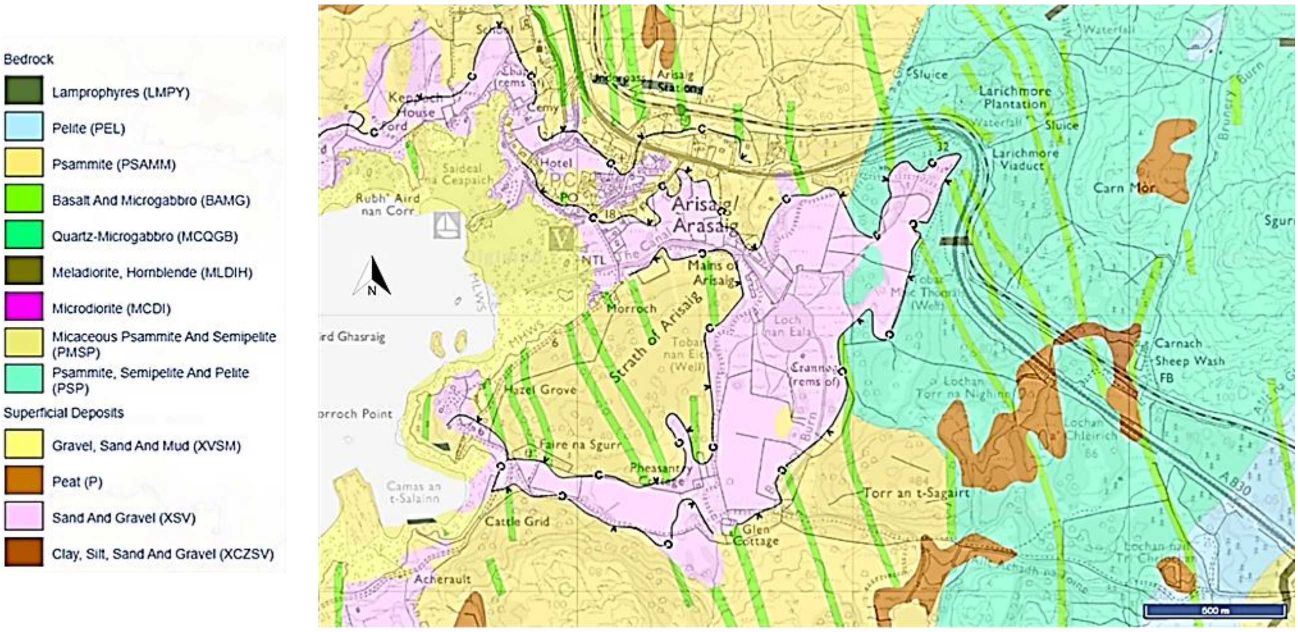


Figure 20 Map of geology in Arisaig area with soils illustrated (created using Digimap, 2022)

The present day Loch nan Eala was reduced in size by the construction of a hand-cut canal at approximately AD 1850 (Mapleton, 1870), which was built to improve drainage and supply a water mill (Highland Regional Council, 1986). With the only connection to the sea through the small valley in which the canal runs (see Figures 10 and 11), the loch remains at a reduced level. The construction of the rock-cut canal from Loch nan Eala to the sea drained the lake and by about 1856 water levels had fallen sufficiently, exposing the remains of a crannog, or prehistoric lake dwelling, within the peat sediments of the main basin (see Figures 3 and 27) (Mapleton, 1870, Shennan *et al.*, 1994). The basin had been alternately exposed to and isolated from marine conditions (Shennan *et al.,* 1994,1995). The thickness of these soft sediments in the basin centre was mentioned within reports by Mapleton (1870) as well as mention of concentrations of oyster (*Ostrea edulis*) shells, with periwinkles (*Littorina littorea*) and whelks (*Buccinum undaturn*) observed within a bed of clay, which was described as 'an old sea bottom'. The clay layer sealed a woody detritus peat layer and was itself covered by approximately 1 m of turfa peat (see Figures 22 and 29) (Shennan *et al.,* 1994).

The minimum altitude of the rock ridge between the upper basin (Figure 22) and Loch nan Ceall, at Camas an t-Salainn, is +15.27 m OD. During high relative sea-level in the Late Devensian there would have been a similar connection to the sea, Present mean spring tidal range in the area is 4.3 m, with mean high water spring tides +2.4 m OD and highest astronomical tides at +2.9 m OD (Shennan *et al*., 1995).

Figure 21 North facing photo of Loch nan Eala with modern vegetation in main basin, Walker (2022)

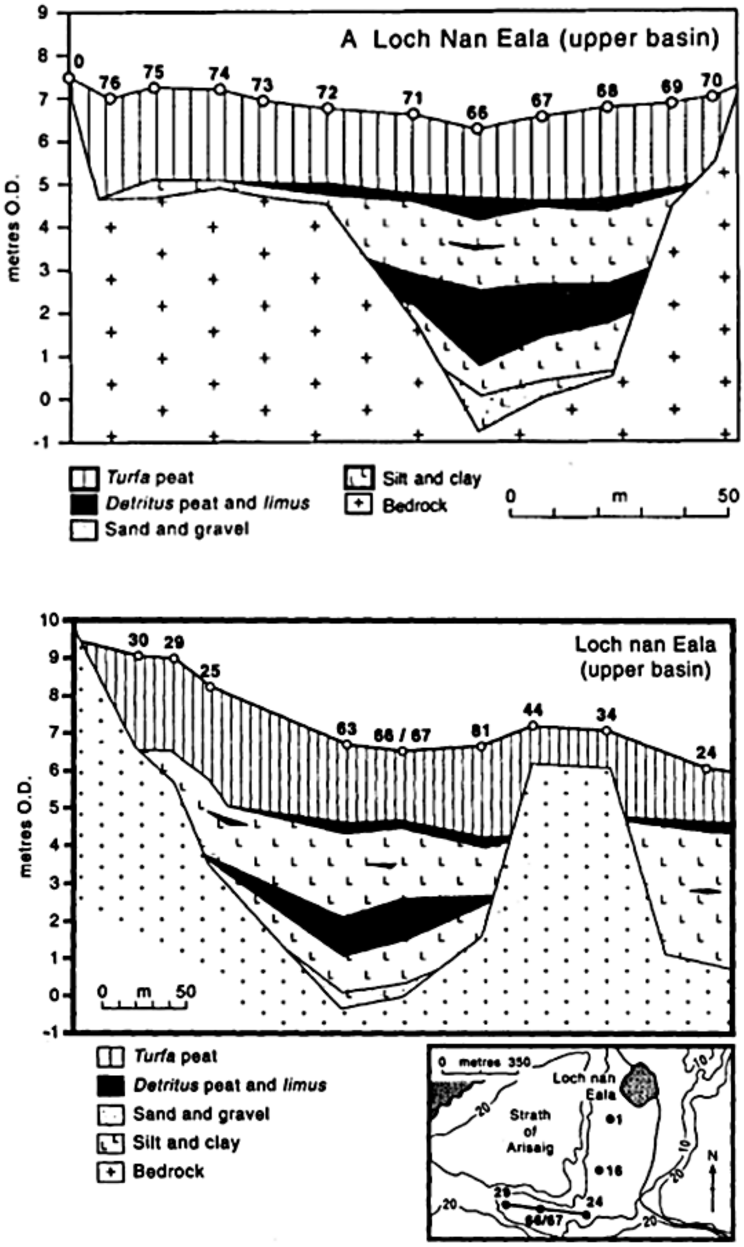


Figure 22 Generalised stratigraphy and previously cored locations in the upper basin of Loch nan Eala Cores 66/67, from Shennan et al. (1994), no stratigraphic diagram was available for the main basin of Loch Nan Eala.

Loch nan Eala now provides improved pasture for cattle and sheep grazing from the drained areas (Shennan *et al*., 1994, 1995) (see Figures 21, 24 and 25). Immediately around the Loch there is a low-lying area with stands of *Alnus glutinosa, Phragmites australis* as well as species-rich herbaceous freshwater fen (see Figures 23, 24 and 25). The low-lying area and parts of the pasture are flooded during periods of high stream discharge, with the main streams draining into Loch nan Eala, Brunery Burn and Allt na Laraiche Moire, rise in the steep hills (over 450 m OD) to the north and northeast (Shennan *et al*., 1994, 1995). The soil consistency of the present day area surrounding Loch nan Eala is light, predominantly sand rich soils (see Figure 23) (Digimap, 2022).

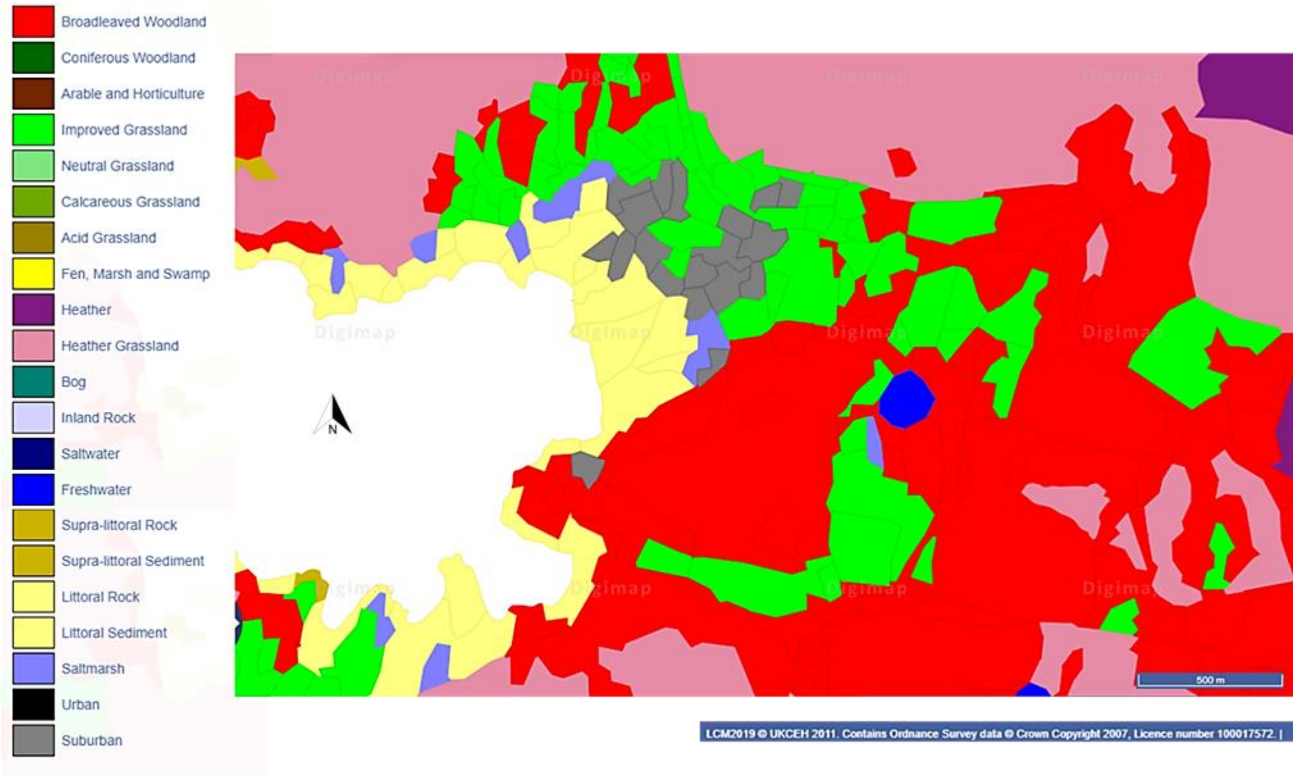


Figure 23 Map of current vegetation in the Arisaig area (created using Digimap, 2022)

Figure 24 Photograph of Loch nan Eala facing north east with current vegetation, taken in February 2022 during relatively high water levels, Walker (2022)

Figure 25 Photograph of current grazing at Loch nan Eala, facing west, Walker (2022)

Figure 26 East facing photo of Loch nan Eala within main basin, taken during winter with high water levels, Walker (2022)

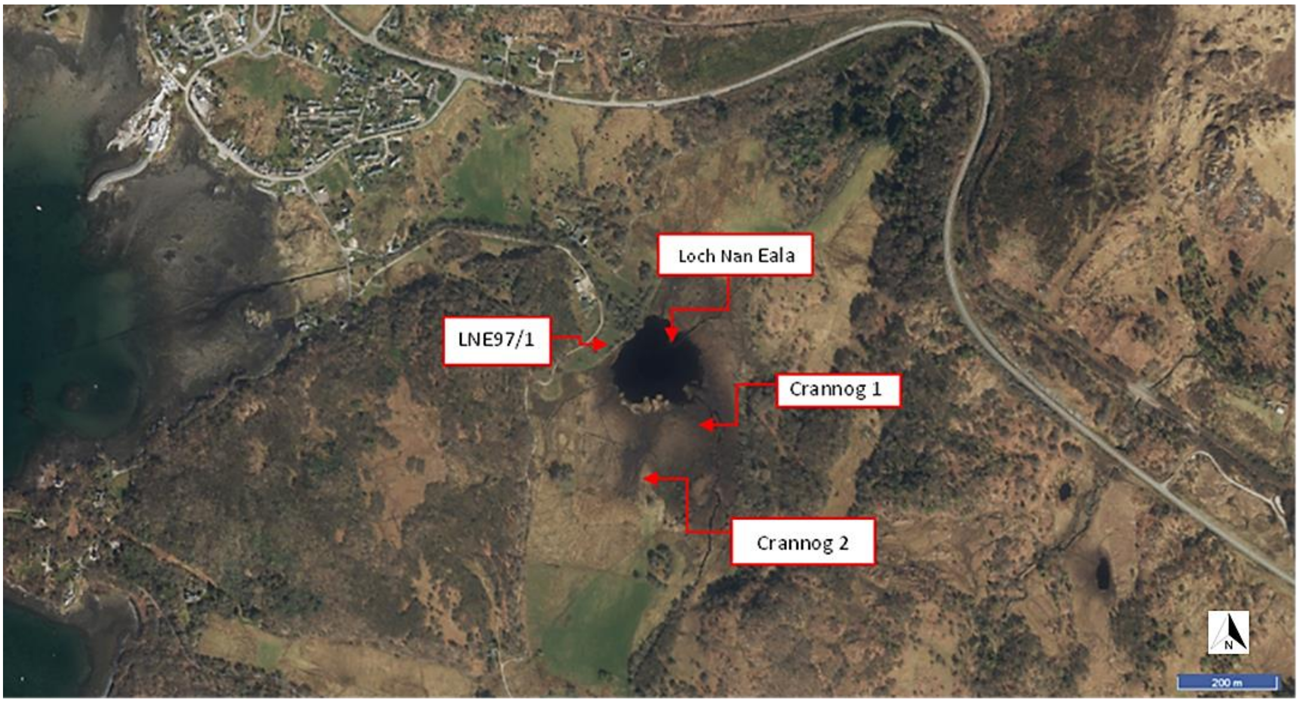


Figure 27 Aerial photograph of Loch Nan Eala with core LNE97/1, crannog 1 and crannog 2 (created using Digimap, 2022)

4.0 Methods

4.1 Collection of core

As the thesis took place during the COVID19 pandemic, no field work allowed by Durham University due to health and safety reasons and government mandates, resulting in limited access to core samples. Core LNE97-1 was deemed suitable by Dr Jeremy Lloyd, it was unused and had been stored within the Durham University cold stores, taken at Loch nan Eala during field work in 1997.

A piston corer was used to extract the core in the north-western area of the loch edge (see Figure 28). The coring was carried out using standard procedures (Fægri and Iversen, 1989). The core labelled as LNE97-1 was taken from the northwest area of Loch nan Eala (see Figure 28 below), located within the main basin. As the cores were extracted by Dr Jeremy Lloyd and Dr Jim Innes in 1997, only a verbal explanation was given for the rationale behind the location of the core. The core was taken to be examined as part of sea level analysis of the late glacial and Holocene period (Lloyd, 2022, pers. Comm.), similar to research done by Shennan et al. (1994, 1995). The location for the site was limited to areas which would provide a deeper core extraction, suitable accessibility and a place within the main Loch nan Eala basin, that is not too close to the edge to stop wash in which may affect the core (Lloyd, 2022, pers. Comm.). When extraction was completed, each section of the core was then placed into plastic tubing and wrapped in plastic sheeting, this ensures drying and shrinkage are kept to a minimum as it can cause deformation of the core (Berglund, 2003). Samples were kept sealed to prevent water loss and the development of mould or fungus, which increase the rate of decomposition. The core was then stored in a cold room at the University of Durham, unused until the present day.

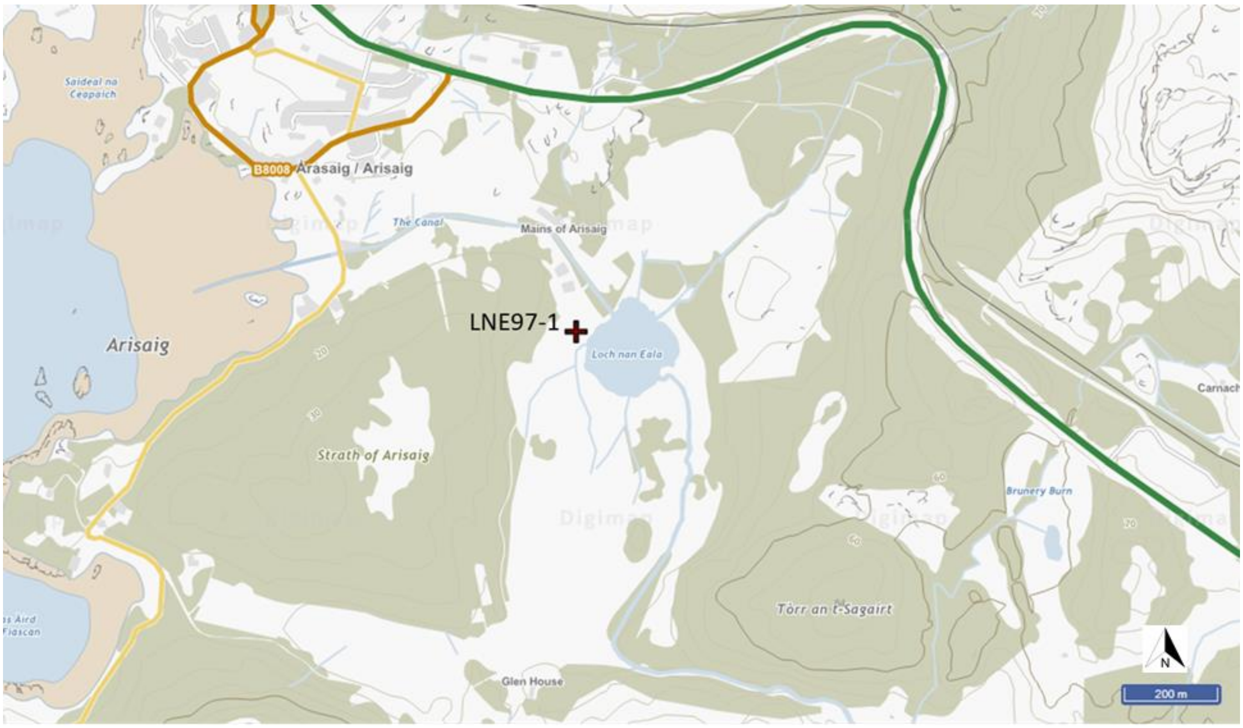


Figure 28 Location of LNE97-1 core, + symbol indicates the location of the core extraction (created using Digimap, 2022)

4.2 Preparation of samples

Pollen samples were prepared in a lab using standard procedures (Moore *et al*., 1991). The chosen process of sample collection was fine resolution pollen analysis (FRPA). Hydrofluoric acid (HF) was not used to remove silica due to safety reasons, the sediment was also mostly organic and would not have required Hydrofluoric acid for the majority of the samples. Marker spores were added to allow the calculation of pollen concentrations and sedimentation rates (Stockmarr 1972). English names for plants, pollen and spores are used with first appearance of each, but throughout the report Latin names will be dominant form of identification.

Samples were taken at intervals every 1 cm, from 155cm to 200cm depth (see Figures 29 and 30). The shallowest depth of the core being 154cm, however, the first 1cm of core at 154cm was disregarded due to shrinkage, 13 more samples were taken every 4cm from 200cm but were discarded due to the sparsity and unusable quality of pollen at lower depths (see Figures 29 and 30).

Due to limitations of COVID19 and refurbishment of the pollen labs at Durham University, there was issues and delays in preparing the pollen for analysis. Limited time allowances were provided to students and staff for lab access. Due to delays, only a total of 45 samples were deemed usable for this thesis. Further limitations on preparation of samples resulted in the thesis only being able to analyse intervals of 1cm rather than redoing any smaller samples at later points in the study.

Figure 29 Initial extraction of samples from core LNE97-1, Walker (2022)

Figure 30 Fine resolution extraction of the core LNE97-1 at every 1cm, Walker (2022)

4.2.1 Concentration of fossil Pollen

The absolute abundance of each pollen type is calculated with reference to the number of exotic spores (*Lycopodium*) encountered in the routine pollen count (Moore *et al.,* 1991). The total number of pollen grains in each cc. was estimated by counting the occurrence of exotic *Lycopodium* spores added to each subsample during preparation. The technique of adding an exotic marker to microscopic samples allows for more precise counting of pollen amount per sample. Benninghof introduced the method in 1962, it relies on knowing the exact number of marker grains within a known volume of material (Faegri *et al*., 1989).

It is noted that although *Lycopodium* can be found native to some habitats in this study, the added spores have been acetylated twice, giving a darker and more distinctive appearance (Chambers *et* *al*., 2011). *Lycopodium* spore tablets (batch 483216) were prepared slightly differently to the described process by Stockmarr (1971, 1973), which was highlighted on batch description dated to 2004. Spore concentration was determined using an electronic particle counter, Coulter Counter ZB (Stockmarr, 1973). Each tablet contained a calibrated approximate of 18583 spores, with calibrated result of 5 tablets containing 92914 spores.

The calculation of total pollen in a 1ml sample involves:

Total pollen counted x Total number of exotic Lycopodium spores (18583 per tablet) ÷ Total counted Lycopodium spores.

Two *Lycopodium* tablets were used per 1ml sample, meaning a total of 37,166 *lycopodium* marker spores would be contained within each sample.

To standardise fossil pollen counts throughout the samples, a correction was applied to eliminate sample weight variations. Another advantage of the technique is that the addition of the tablets takes place after sediment has been collected, but prior to the main preparation steps so that any material lost during the process has the same numerical effect on the fossil pollen as on the added exotic *Lycopodium* spores, not changing the pollen to exotic spore ratio.

4.2.2 Non-pollen Palynomorphs

Non-pollen Palynomorphs or NPP grains were counted alongside pollen grains using a standard identification chart (van Geel, B., 2001) as well as the NPP-ID; non pollen palynomorph database server (http://non-pollen-palymorphs.uni-goettingen.de). NPP were counted during the pollen counting process and stopped counting when pollen reached a total of 300 TLP. Their presence is useful for later interpretation and analysis.

4.2.3 Charcoal analysis

A simple point count method from Clark (1982) was used to record charcoal within the sample. Percentages are based on total land pollen and charcoal concentrations are in terms of fragments >10μm per pollen grain. This ensured that charcoal was counted alongside the pollen grains and NPP, without having to make new slides. The rationale behind this was the acknowledged low amounts of microcharcoal seen in the area from Shennan et al. (1994, 1995), suggesting there was a likelihood of low quantities being present in core.

4.3 Data collection

Pollen and spore identification is based on Moore *et al*. (1991), the pollen reference collection at Durham University. Stratigraphically constrained cluster analysis in CONISS was used to numerically determine the different pollen zones (Grimm, 1991). Diagrams were created using C2, all pollen species were recorded, but only species with abundance >1% are illustrated in figures. The pollen sum consists of a minimum of 300 total land pollen grains (TLP), excluding aquatics and spores. Percentage values for taxa outside the TLP sum were calculated as TLP + taxon/group whilst non-pollen sums were calculated as a percentage of TLP (Davies and Tipping, 2003). Percentage pollen data is presented for each 1 cm sample intervals, plotted against depth, then against calibrated years BP.

4.4 Radiocarbon dates

Three ^{14}C dates were also collected. Samples were collected and submitted to Queens University, Belfast after receiving the 14CHRONO funding grant from the QRA radiocarbon award in July 2021. Three radiocarbon dates were awarded and were taken at depths of 155cm, 176cm and 196cm. The core analysed covers a period of time of approximately 1850 - 2050 years in length, dating from the Late Neolithic to late Bronze Age with no evidence for truncation or major hiatuses. Data was calibrated using Bchron package (see Haslett, and Parnell, 2008) (see Figures 34, 35 and 36). Calculated accumulation rates have varied (0.15 mm/yr increasing to 0.36 mm/yr), but sample resolution is high throughout, approximately 67 years per sample in the lower section of the core reducing to 28 years per sample in the upper section analysed (Figures 31 to 36).

Samples were taken and listed as LNE97/155 for 155cm depth this was labelled as UBA-46260 in the lab (as seen in Figure 31), LNE97/176 for 176cm depth, labelled as UBA-46261 in the lab and LNE97/196 for 196cm depth, labelled as UBA-46262 in the lab.

UBANo	Sample ID	Material Type	^{14}C Age	±	F14C	±	mg Graphite
UBA-46260	LNE97/155	Lake sediment	2714	26	0.7133	0.0023	0.993
UBA-46261	LNE97/176	Lake sediment	3148	31	0.6757	0.0026	0.983
UBA-46262	LNE97/196	Lake sediment	4225	48	0.5910	0.0035	0.304

Figure 31 Raw data for ^{14}C dates sent by Queens University, Belfast (Reimer et. al., 2020)

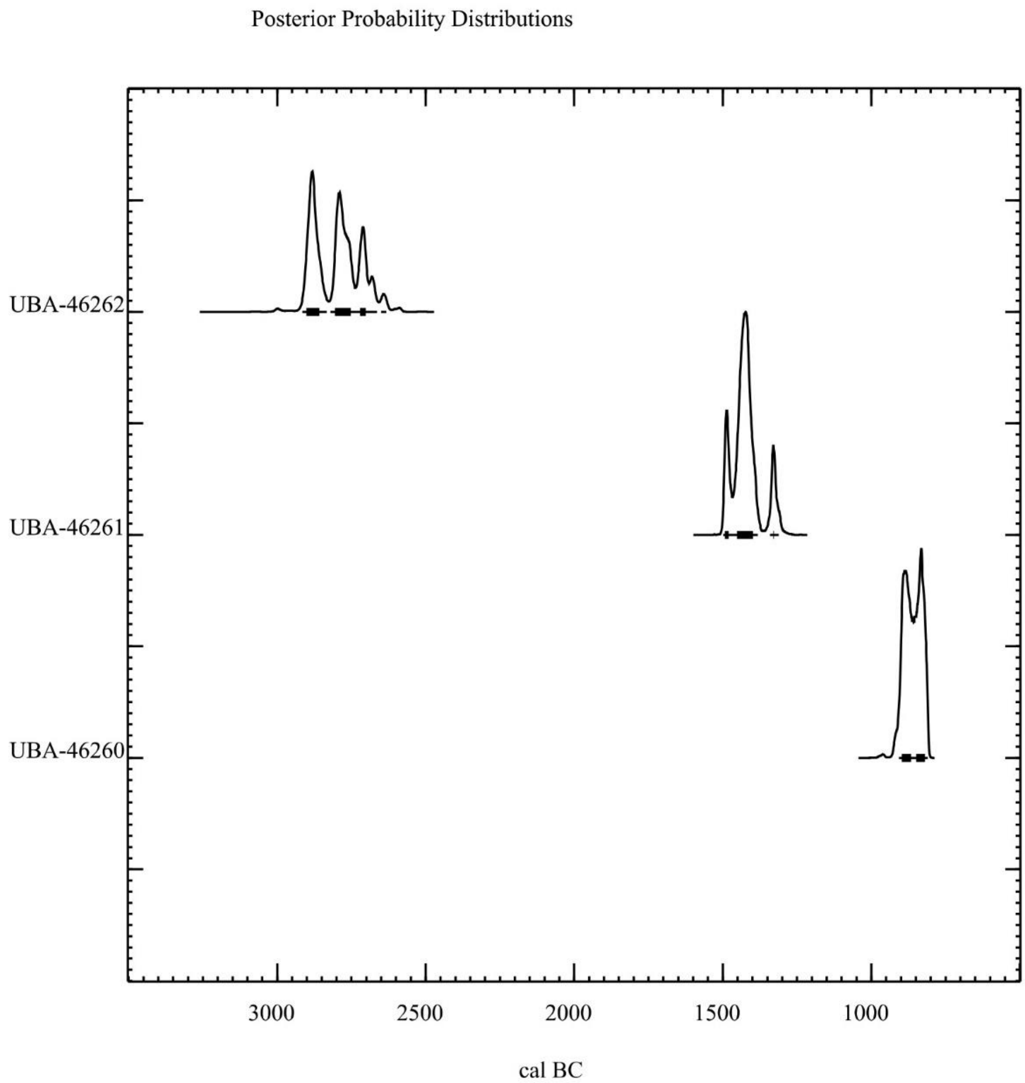


Figure 32 Posterior Probability Distributions from Queens University Belfast 14C results given in Cal BC (Reimer et. al., 2020)

			Cal BP (2σ)				Cal BC (2σ)	
Depth (cm)	Age (14C)	error	min	max		Mid-point	min	max
155	2714	26	2759	2856	48.5	2807.5	810	907
176	3148	31	3331	3448	58.5	3389.5	1382	1499
196	4225	48	4613	4864	125.5	4738.5	2664	2915

Figure 33 Radiocarbon dates data, presented in Cal BP and Cal BC, calibrated using Calib Rev 8.1.0, within main R package, using Bchron package (see Haslett, and Parnell, 2008)

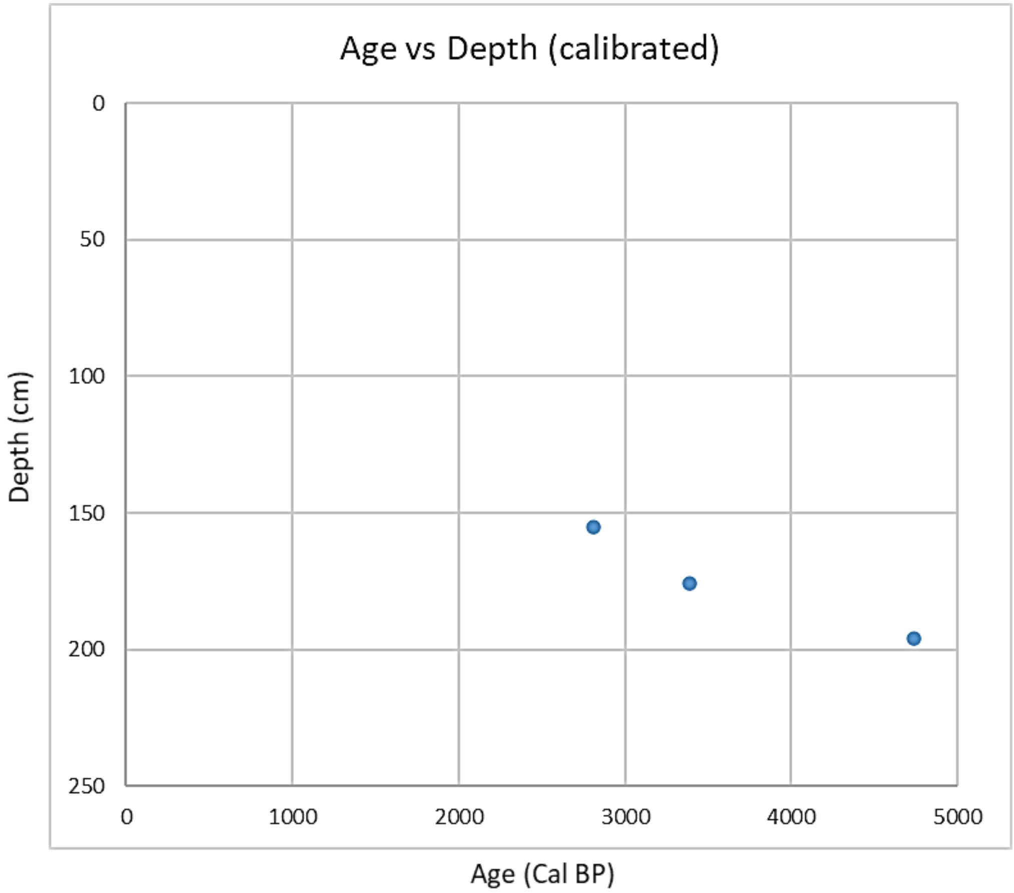


Figure 34 Age vs Depth model for calibrated ^{14}C dates, using Calib Rev 8.1.0, plotted Age in Cal BP against depth in cm. Calibrated within main R package, using Bchron package (see Haslett, and Parnell, 2008).

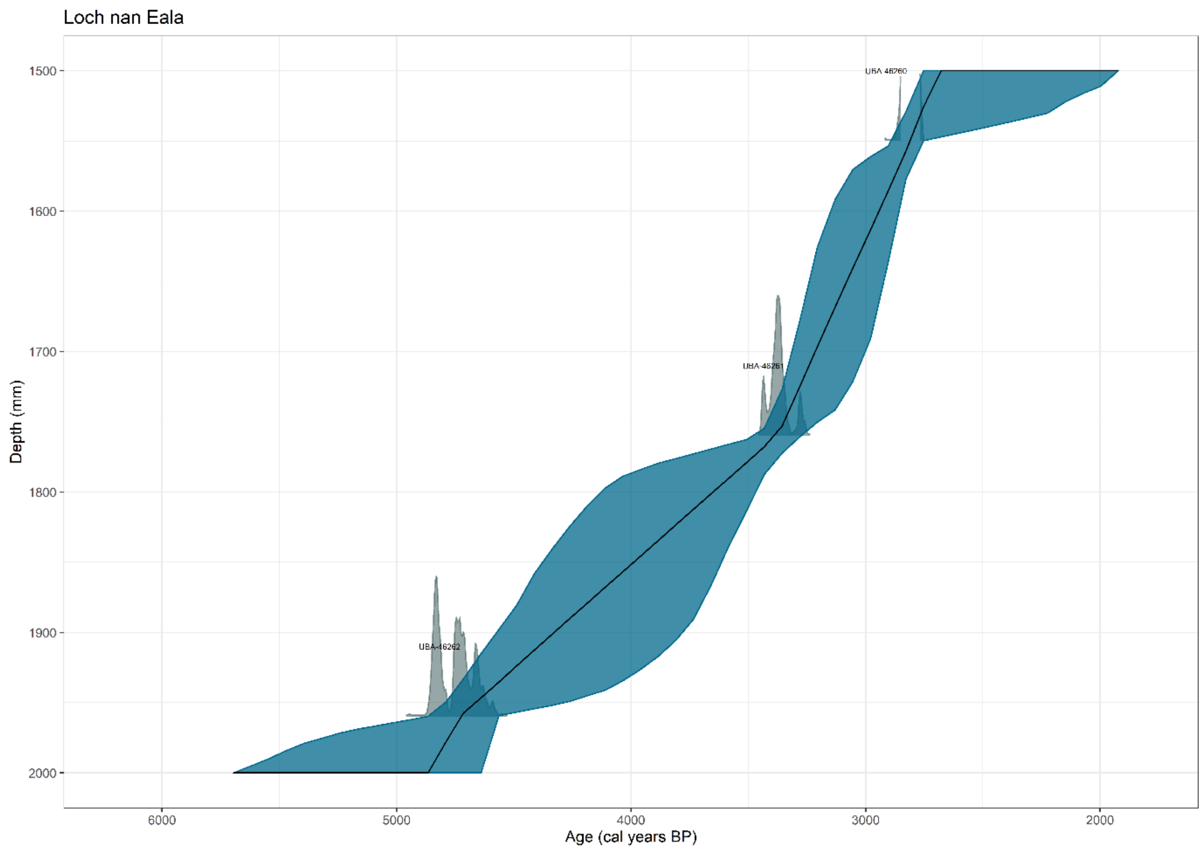


Figure 35 Age Depth model 1 from core LNE97-1 of calibrated ^{14}C dates, using Calib Rev 8.1.0, plotted Age in Cal BP against depth in cm. Calibrated within main R package, using Bchron package (see Haslett, and Parnell, 2008).

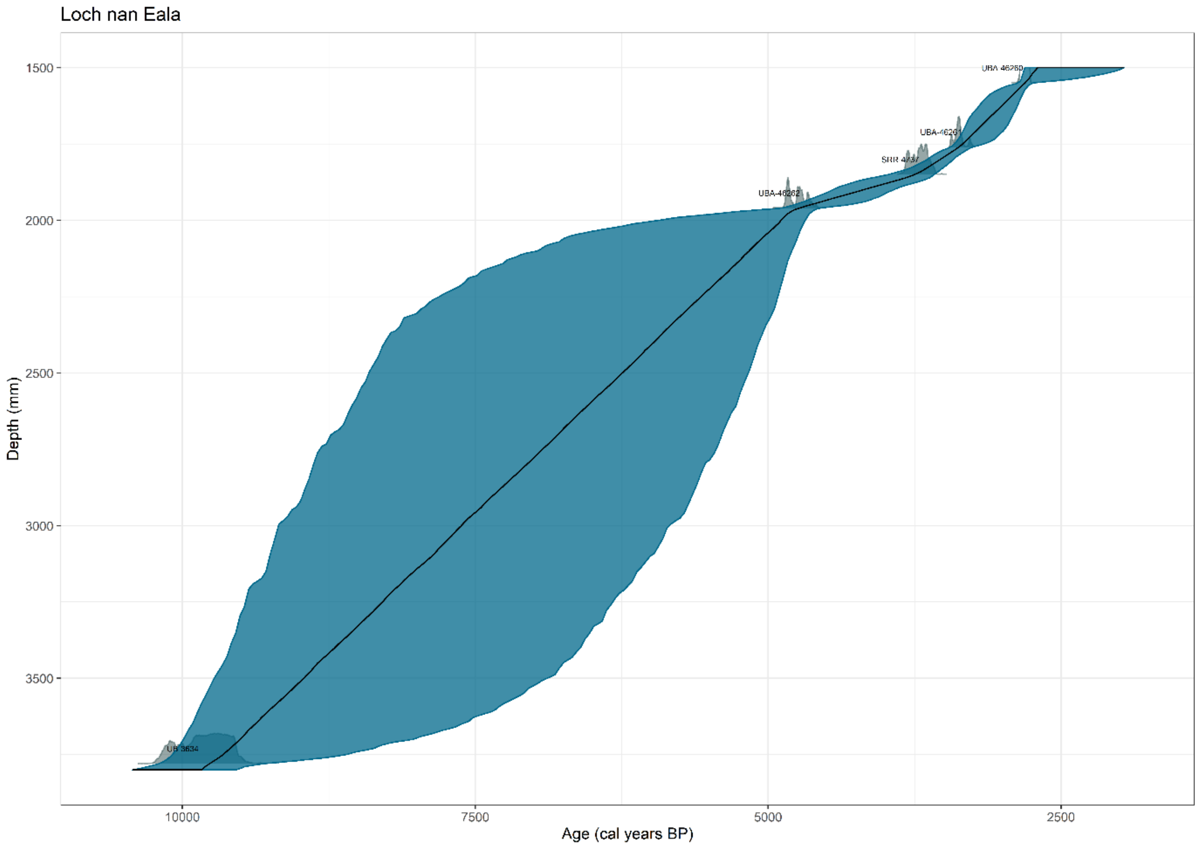


Figure 36 Age Depth model 2 from core LNE97-1 of calibrated ^{14}C dates, using Calib Rev 8.1.0, plotted Age in Cal BP against depth in cm. Calibrated within main R package, using Bchron package (see Haslett, and Parnell, 2008).

5.0 Data results

5.1 Overview of samples

An overall total of 15,426 pollen grains were counted from 45 samples from core depths ranging from 155 cm to 200 cm. The target count of pollen per sample was 300 land pollen. Total pollen counted ranged from 302 to 418. The shallower, more recent peaty layers and the deeper silty clay layers were found to have significantly more sparse pollen grains. Many of the samples were found to have poor to very poor preservation, this was noted during counting, but did not impede the total land pollen counts. It was noted that within the slides, fragments of NPPs such as Mandibula of arthropods were seen, but these were not counted.

To gain the most accurate overview of the vegetational change, samples were taken at a fine resolution of every 1cm from 155 cm down 200 cm in the core, (as discussed in Chapter 4.0). The aim of sampling at high resolution was to try to identify any areas of possible human activity present in the landscape, and to build a detailed picture of the changes in vegetation patterns potentially associated with environmental changes at Loch Nan Eala covering the period from 2810 to 4878 Cal BP.

An additional 13 samples were processed from 204 cm to 256 cm. However, on inspection, pollen abundance was very low in these samples and preservation was very poor. Also, these samples, coming from lower down in the silty clay unit, are likely to be significantly older than the section of most interest, hence they have not been included in the detailed analysis presented here. It was decided that 200 cm depth was the final depth of investigation, due to the low frequency of pollen and also the period of interest being more recent.

5.1.1 Lithostratigraphy of core LNE97/1

The core base is characterised by a light greyish brown silty clay with the overlying limus containing some plant fragments and silty clay (see Figures 37 and 38). The core then transitions to an organic rich (limus) silty clay, a layer of rich organic settling. Overlying is a silty clay with organic material. The deepest layer which was analysed within the study contains a mixed silt-clay-limus deposit with frequent mica, this then gradually transitions into an organic rich silty clay/peat, which is finally sealed by a fibrous peat layer with plant fragments (see Figures 37 and 38). The detailed stratigraphic record from the relevant parts of the core is shown as in Figures 37 and 38 respectively. A comparative figure was created to compare the core taken by Shennan *et al*. (1994) with the core sequences taken from LNE97/1 (see Figures 37 and 38). The clastic material represents a high flux of silt and clay into the basin, most likely from a marine source, but it also represents low productivity. The transition to the limus layer represents a likely increased productivity, also potentially associated with a reduction in flux of silt and clay into the basin (possibly due to isolation from the sea). Similar in aspects to Shennan *et al*. (1994). The core LNE97/1 used within this study ends at 155 cm, whilst the core LNE66/67 from Shennan *et al.* (1994) reaches 0cm depth. The lowest ^{14}C date produced was 4738.5 ± 125.5 Cal BP at 196cm, and the top ^{14}C date at 155cm dating to 2807.5 ± 48.5 Cal BP. The oldest sea-level index point from Shennan *et al*. (1994) was 10,500 ± 90 BP, which is located at the base of the limnic detritus peat.

Depth (cm)	Munsell colour	Description	Notes
155 - 180	Very dark brown 10YR 2/2	Fibrous peat with plant fragments (Th3, Sh1)	Contemporary moss roots and other detritus
181 - 192	Dark brown 10YR 3/1	Organic material, plant fragments becoming less common with depth (Sh3, (As + Ag)1)	Moderate Mica inclusions root detritus
192 - 202	Dark greyish brown 10YR 4/1	Silty clay with occasional plant fragments ((As + Ag)2, Sh2)	Frequent Mica inclusions
202 - 223	Medium greyish brown	Silty clay with organic material ((As + Ag)3, Sh1)	(Not analysed)
223 - 355	Dark greyish brown	Organic rich (limus) silty clay (Ld2, (As + Ag)2)	(Not analysed)
355 - 505	Dark brown	Limus with some plant fragments and silty clay (Ld3, (As + Ag)1)	(Not analysed)
505 - 552	Light greyish brown	Silty clay ((As + Ag)4)	(Not analysed)

Figure 37 Detailed stratigraphic record of sample layers from core LNE97/1. Classification based on the Tröels-Smith scheme: Th = Turfa herbacea (peat); Sh = Substantia humosa (humified organic material); As = Argilla steatoides (clay); Ag = Argilla granosa (silt), Ld = Limus (fine grained organic mud, lake deposit). [The Tröels-Smith scheme divides the sediment into quarters, i.e., the components must add up to 4].

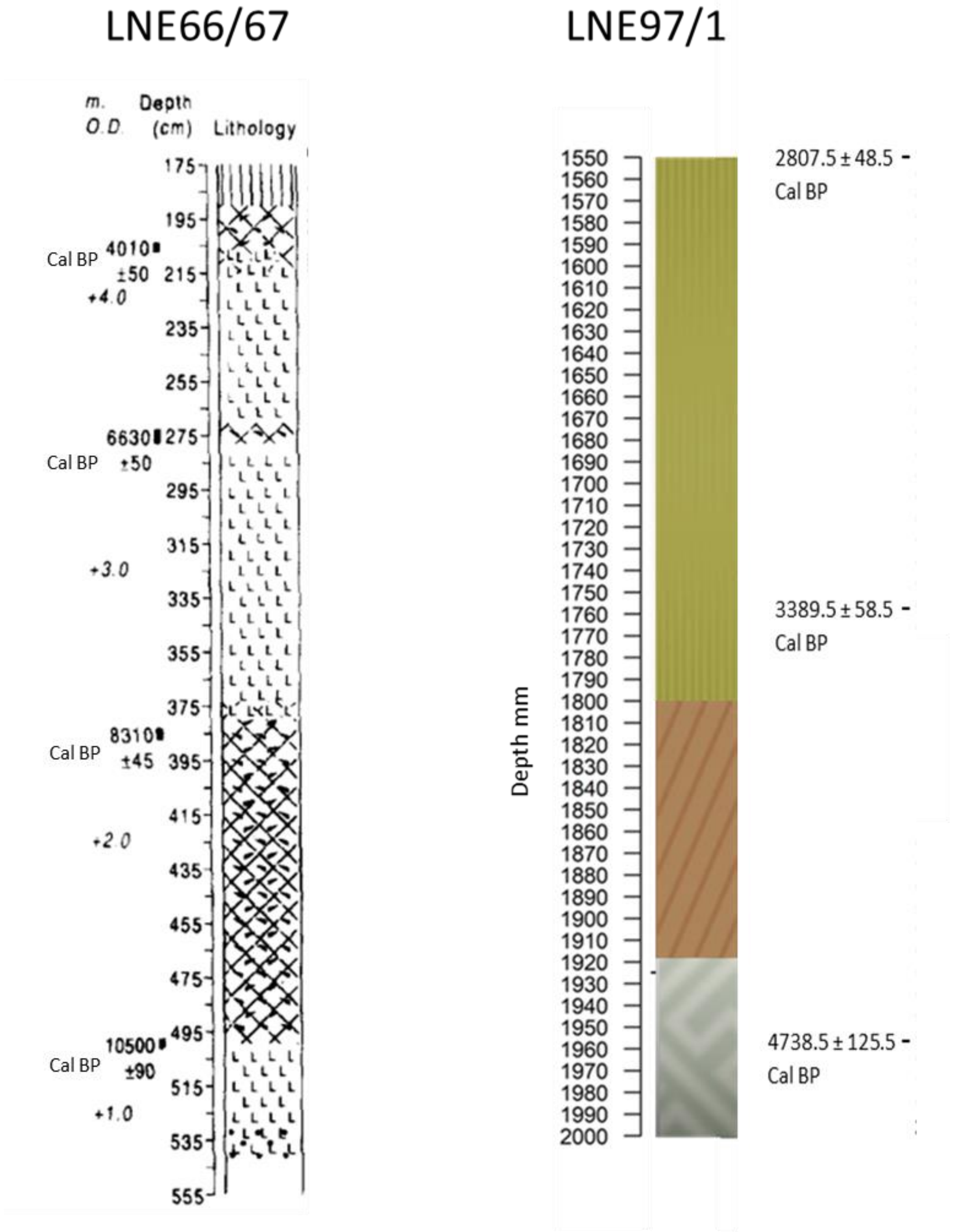
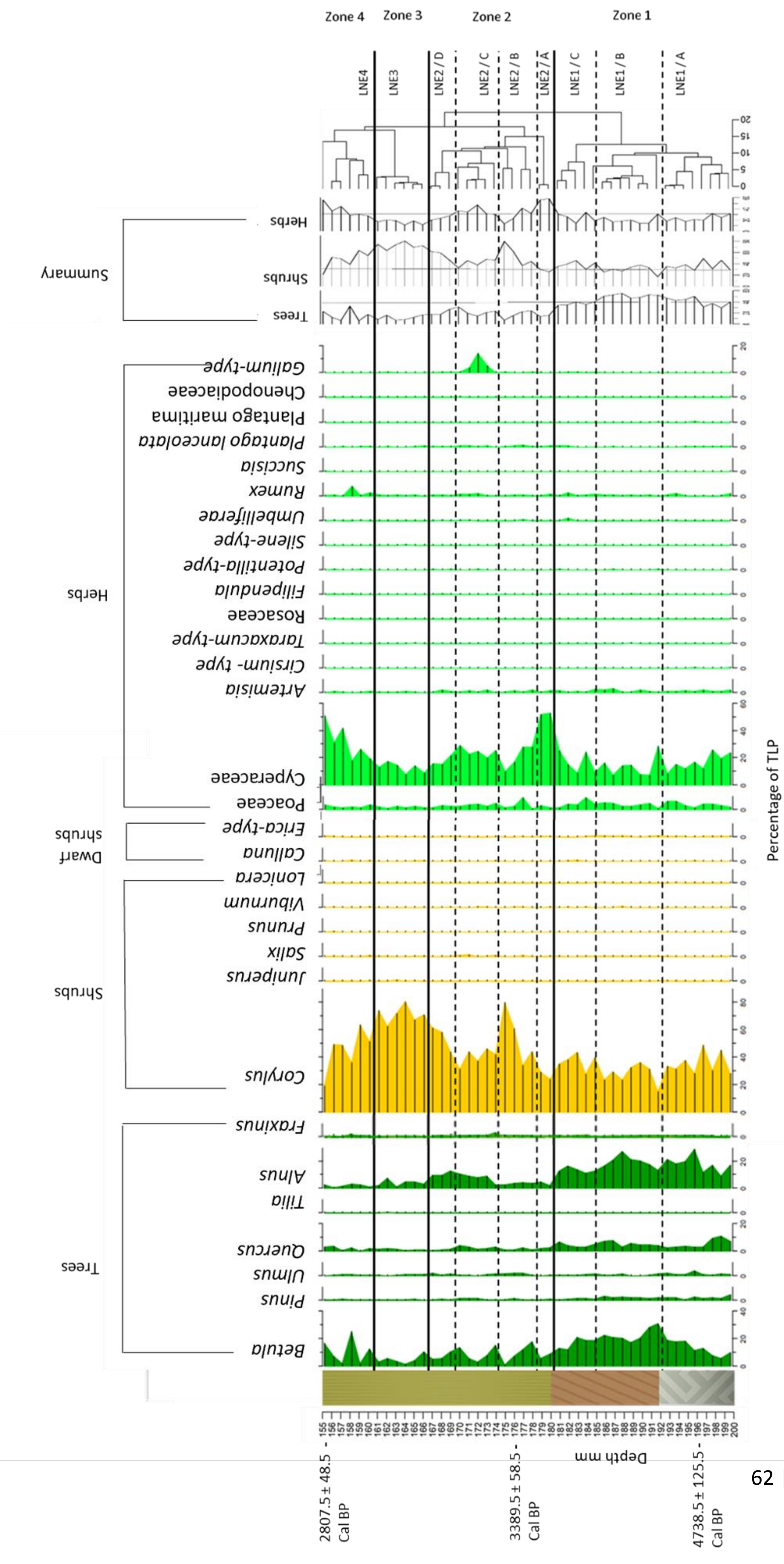


Figure 38 Record of stratigraphic cores from Shennan et al. (1994) and core from this study LNE97/1 with ^{14}C dates marked at 155cm, 176cm and 196cm depth. On the left: Green indicates fibrous peat with plant fragments, Brown indicates organic material and Grey indicates silty clay with occasional plant fragments.

5.1.2 Palynology of core LNE97/1

The detailed results of pollen counts are presented in Figures 39 and 40 plotted against depth scale with the dendrogram produced by the cluster analysis. Based on the cluster analysis the core can be sub-divided into four major zones. A combination of the cluster analysis results and qualitative interpretation of the pollen spectra was then used to identify the seven sub zones illustrated.



Zone 4
Zone 3
Zone 2
Zone 1
LNE4
LNE3
LNE2 / D
LNE2 / C
LNE2 / B
LNE2 / A
LNE1 / C
LNE1 / B
LNE1 / A
Summary
Trees
Shrubs
Herbs
Galium-type
Chenopodiaceae
Plantago maritima
Plantago lanceolata
Succisia
Rumex
Umbellifferae
Silene-type
Potentilla-type
Filipendula
Rosaceae
Taraxacum-type
Cirsium- type
Artemisia
Cyperaceae
Poaceae
Dwarf shrubs
Erica-type
Calluna
Lonicera
Viburnum
Prunus
Salix
Juniperus
Corylus
Fraxinus
Alnus
Tilia
Quercus
Ulmus
Pinus
Betula
Percentage of TLP
Depth mm
2807.5 ± 48.5 Cal BP
3389.5 ± 58.5 Cal BP
4738.5 ± 125.5 Cal BP

Figure 39 Total pollen counts from core LNE97/1 with ^{14}C dates and stratigraphy of core. Black lines indicate pollen zones identified based on stratigraphically constrained cluster analysis (CONISS) using Rioja (see *Juggins, 2020), dashed lines indicate sub-zones identified based on qualitative trends in pollen spectra.*

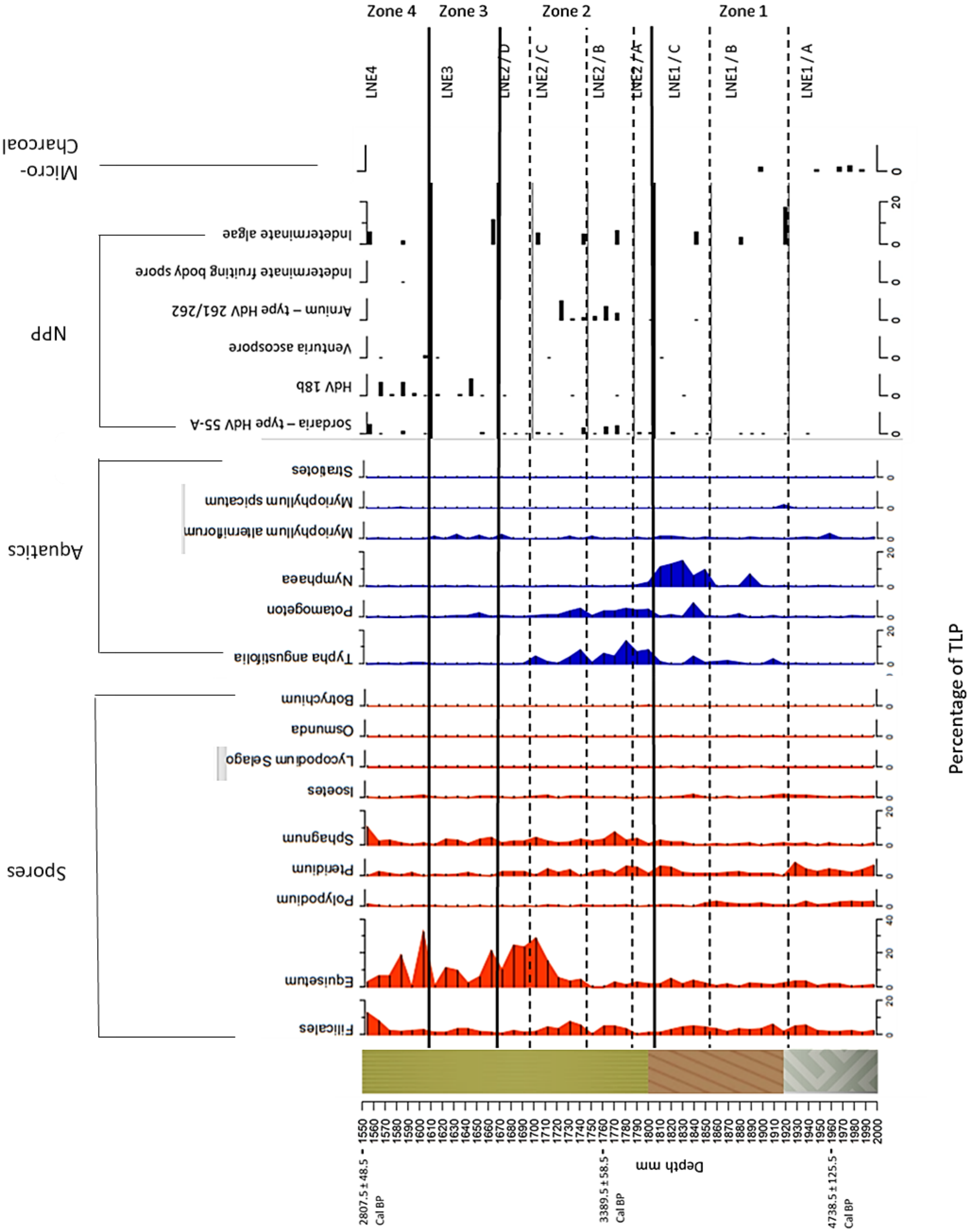


Figure 40 Total percentages based on land pollen counts TLP, with aquatic pollen, spores, NPP data and microcharcoal from core LNE97-1. Black lines indicate pollen zones identified based on stratigraphically constrained cluster analysis (CONISS) using Rioja (see Juggins, 2020), dashed lines indicate sub-zones identified based on qualitative trends in pollen spectra.

Table 3 Raw data for general preservation, inclusions, NPP data and Charcoal data from core LNE97/1, Scale of preservation of pollen based on Cushing (1967) five categories of preservation based upon the physical appearance of the pollen grain: well-preserved, broken, crumpled, corroded and degraded.

Depth (Cm)	Sample number	Zone	Dominant Taxa	Preservation	Presence of NPP	Presence of Charcoal	Comments
200	18	LNE1 A	*Corylus-type*, Cyperaceae, *Alnus*	Broken, corroded & degraded	No	Yes	High frequencies of Mica
199	76	LNE1 A	*Corylus-type*, Cyperaceae	Broken & degraded	No	Yes	High frequencies of Mica
198	75	LNE1 A	*Corylus-type*, Cyperaceae, *Alnus*	Broken & degraded	No	Yes	High frequencies of Mica
197	74	LNE1 A	*Corylus-type*, Cyperaceae, *Betula*	Broken & degraded	No	No	High frequencies of Mica
196	17	LNE1 A	*Corylus-type*, Cyperaceae, *Alnus, Betula*	Broken & degraded	No	No	High frequencies of Mica
195	73	LNE1 A	*Corylus-type*, *Alnus, Betula*	Broken & degraded	No	Yes	High frequencies of Mica
194	72	LNE1 A	*Corylus-type*, Cyperaceae, *Alnus, Betula*	Corroded	Sordaria-type HdV 55-A	Yes	High frequencies of Mica
193	71	LNE1 A/B	*Corylus-type*, *Alnus, Betula*	Degraded	No	No	High frequencies of Mica
192	16	LNE1 B	Cyperaceae, *Betula*	Degraded	Sordaria-type HdV 55-A, HdV 18, Indet. Algae	No	Low frequencies of Mica
191	70	LNE1 B	*Corylus-type*, *Alnus, Betula*	Corroded	No	No	Low frequencies of Mica
190	69	LNE1 B	*Corylus-type*, *Alnus, Betula*	Corroded	Sordaria-type HdV 55-A	No	Low frequencies of Mica
189	68	LNE1 B	*Corylus-type*, Cyperaceae, *Alnus, Betula*	Corroded	Sordaria-type HdV 55-A	No	Low frequencies of Mica

188	15	LNE1 B	*Corylus-type*, *Alnus, Betula*	Corroded	Sordaria-type HdV 55-A, Indet. Algae	No	Low frequencies of Mica
187	67	LNE1 B	*Corylus-type*, *Alnus, Betula*	Corroded & degraded	No	No	Low frequencies of Mica
186	66	LNE1 B/C	*Corylus-type*, Cyperaceae*,* *Alnus, Betula*	Corroded	No	Yes	Low frequencies of Mica
185	65	LNE1 C	*Corylus-type*, *Alnus, Betula*	Corroded	Sordaria-type HdV 55-A	Yes	Low frequencies of Mica
184	14	LNE1 C	*Corylus-type*, Cyperaceae, *Betula*	Corroded	Arnium - type HdV 261/262, Sordaria-type HdV 55-A, Indet. Algae	No	V.Low frequencies of Mica, boundary layer for detritus peat
183	64	LNE1 C	*Corylus-type*, Betula	Degraded	HdV 18	No	N/A
182	63	LNE1 C	*Corylus-type*, Cyperaceae*,* *Alnus, Nymphaea*	Corroded	Sordaria-type HdV 55-A	No	N/A
181	62	LNE1 C/D	*Corylus-type*, Cyperaceae, *Betula, Alnus, Nymphaea*	Corroded	Venturia ascospore	No	N/A
180	13	LNE1 D	Cyperaceae, *Corylus-type*	Corroded	Arnium - type HdV 261/262, Sordaria-type HdV 55-A	No	N/A
179	61	LNE1 D/ LNE2 A	Cyperaceae, *Corylus-type*	Corroded & degraded	Sordaria-type HdV 55-A	No	N/A
178	12	LNE2 A	*Corylus-type*, Cyperaceae	Degraded	Sordaria-type HdV 55-A	No	N/A
177	60	LNE2 A	*Corylus-type*, Cyperaceae	Corroded	Arnium-type HdV 261/262, Sordaria-type HdV 55-A, HdV 18b, Indet. Algae spore	No	N/A
176	11	LNE2 A	*Corylus-type*	Broken & degraded	Arnium-type HdV 261/262, Sordaria-type HdV 55-A	No	N/A

175	59	LNE2 A/B	*Corylus-type*	Corroded	Arnium-type HdV 261/262, Sordaria-type HdV 55-A	No	N/A
174	10	LNE2 B	*Corylus-type*, Cyperaceae, *Betula*	Corroded	Sordaria-type HdV 55-A, Arnium-type HdV 261/262, HdV 18b, Indet. Algae spore	No	N/A
173	58	LNE2 B	*Corylus-type*, Cyperaceae	Degraded	Arnium-type HdV 261/262, Sordaria-type HdV 55-A	No	N/A
172	9	LNE2 B	*Corylus-type*, Cyperaceae	Corroded	Arnium-type HdV 261/262, Sordaria-type HdV 55-A	No	N/A
171	57	LNE2 B	*Corylus-type*, Cyperaceae	Degraded	Sordaria-type HdV 55-A, Venturia ascospore	No	N/A
170	8	LNE2 B	*Corylus-type*, Cyperaceae, *Equisetum*	Degraded	Sordaria-type HdV 55-A, Indet. Algae	No	N/A
169	56	LNE2 B/C	*Corylus-type, Cyperaceae, Equisetum*	Degraded	Sordaria-type HdV 55-A	No	N/A
168	7	LNE2 C	*Corylus-type*, *Equisetum*	Degraded	Sordaria-type HdV 55-A	No	N/A
167	55	LNE2 C	*Corylus-type*, Cyperaceae	Corroded	Sordaria-type HdV 55-A, HdV 18b	No	N/A
166	6	LNE2 C	*Corylus-type*, *Equisetum*	Corroded	Indet. Algae	No	N/A
165	54	LNE2 C	*Corylus-type*, Cyperaceae	Corroded	Sordaria-type HdV 55-A, HdV 18b	No	N/A
164	5	LNE2 C/ LNE 3	*Corylus-type*	Corroded	HdV 18b	No	N/A
163	53	LNE3	*Corylus-type*	Corroded	HdV 18b	No	N/A
162	4	LNE3	*Corylus-type, Cyperaceae, Equisetum*	Corroded	No	No	N/A

161	52	LNE3	*Corylus-type*	Corroded	HdV 18b, Venturia ascospore	No	N/A
160	3	LNE3	*Corylus-type*, *Equisetum*	Degraded	Sordaria-type HdV 55-A, HdV 18b	No	V. high freq of Equisetum
159	51	LNE3	*Corylus-type*, Cyperaceae	Corroded	HdV 18b	No	V. high freq of HdV 18
158	2	LNE3/ LNE4	*Corylus-type*, Betula, *Equisetum*	Corroded	Sordaria-type HdV 55-A, HdV 18b, Indet. Fruiting body spore, Indet. Algae	No	N/A
157	50	LNE4	*Corylus-type*, Cyperaceae	Degraded	HdV 18b	No	N/A
156	1	LNE4	*Corylus-type*, Cyperaceae	Degraded	Sordaria-type HdV 55-A, HdV 18b, Venturia ascospore	No	N/A
155	49	LNE4	Cyperaceae	Degraded	Sordaria-type HdV 55-A, HdV 18b, Indet. Algae	No	V. high freq of HdV 18

5.2 Description of individual zones and sub-zones

5.2.1 LNE1: 200 cm – 181 cm

5.2.1.1 LNE1/A: 200 cm – 193 cm

Corylus-type, Alnus, Betula, Quercus, Cyperaceae

LNE1/A consists of 8 samples; 200cm – 193cm depth dating to approximately 4880 – 4460 Cal BP (Late Neolithic – Early Bronze Age).

Pollen was not counted from samples deeper than 200 cm due to poor preservation and sparseness of pollen grains, hence this LNE1/1A begins at the start of the counted samples at 200 cm. The base of this subzone is characterised by a mixed silt-clay-limus deposit ((As + Ag)2, Sh2), gradually transitioning into an organic rich silty clay/peat at the top of LNE1/A. There are frequent mica inclusions within the layer (see Figure 39 and 40).

Sub zone LNE1/A begins with *Corylus-type* (hazel/bog myrtle) pollen as the highest percentage taxon and peaks at 50% of Total Land Pollen (TLP) at 197 cm. Tree species show moderately high percentages throughout the subzone *Alnus* (Alder) between 20- 30%, *Betula* (Birch) at 10-20% and *Quercus* (Oak) 5-10%. Overall, Tree pollen has steady rates of cover throughout the zone ranging from 30 – 50% total TLP, however, none are as prominent as *Corylus-type.* Cyperaceae (Sedge) is also relatively abundant in this subzone, 25% of TLP. The relative abundance of *Pinus* (Pine) at this level is rather low at approximately 5%, meaning there may have been small pockets of pine present on the drier locations within the catchment. *Quercus* pollen has a sudden decrease at 197 cm to <5% and continues at low levels throughout the zone. The overall zone appears to be fairly wooded with a range of tree species and also shrub and herb cover.

Throughout sub zone A, *Corylus-type* maintains dominance, although at 196 cm, it is rivalled by *Alnus*, which peaks to just under 30%. *Corylus-type* and *Alnus* can both tolerate damper conditions, so dominance of the two species suggests a damper environment. Cyperaceae maintains a steady presence throughout the sub zone, suggesting herbs are consistency present in the landscape around Loch nan Eala. Throughout this subzone Poaceae (grass) pollen shows a relatively low, but stable abundance (<10%), but shows a slight increase towards the top of the zone where Cyperacea dips at 193 cm, perhaps demonstrating a chance for Poaceae to flourish. *Artemisia* (Mugwort) is present in low abundances throughout this zone (1-2% TLP), *Rumex* (Common Sorrel) and *Plantago lanceolata* (Ribwort Plantain) are present occasionally in samples throughout this zone. *Betula* pollen present most likely represents *Betula pubescens* or *tremula* and was probably present in the damper areas around the water body, similarly to *Corylus-type* and *Alnus*. *Plantago maritima* (Sea Plantain) is present in one sample through this subzone (196 cm) in low abundances (approx. 1 %), suggesting there may be presence of salt marshes on the edges of the loch. Pollen Palynomorphs present in sub zone A are limited to small percentages of *HdV Type 18b Ascospore* which commonly relate to *Eriophorum* (common cottongrass or cottonsedge), it occurs in consistent low percentages of roughly 1 - 3% throughout most samples in sub zone A.

Aquatics appear very low in numbers within sub zone A. Aquatics have been calculated as a percentage of TLP, without impacting on final TLP percentages. A slight spike in *Myriophyllum alterniflorum* (water-milfoil/ alternate flower watermilfoil) is seen at 196 cm, reaching a peak of 5%. Spore levels remain overall low for sub zone A, *Pteridium* (Bracken) is present as the highest spore seen within the sub zone at 3 - 10%. *Polypodium, Filicales* and Equisetum are the only other notable spores which are present in very low percentages of 2 -3% throughout the sub zone. Microcharcoal occurs at very low rates throughout the sub zone, with between 2 - 7 fragments counted in samples.

Within this sub zone, it appears that there is a fairly rapid interchanging dominance between overall tree and shrub as the highest percentage TLP. Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type, Alnus, Betula, Quercus* with intermittent Cyperaceae, likely in the wetter areas closer to the loch edges. *Pteridium* is present in low percentages and is likely growing in the area in small amounts. Similarly, small quantities of *Myriophyllum alterniflorum* would have likely been present within the loch itself. Low levels of charcoal indicate some burning in the catchment area within LNE1/A. Pollen had poor to very poor preservation with high degradation and moderate to high sparsity, 138,000 to 296,000 pollen per cm^3, (see Figure 41), making the counting process more difficult in some samples. Possible fluctuations in water drainage may have contributed to issues with palynological survival potentially associated with the marine channel present at the time. Fluctuations in water levels can attribute to the poor preservation of the pollen itself (Bercovici and Vellekoop, 2017).

5.2.1.2 LNE1/B: 192 cm – 186 cm

Corylus-type, Alnus, Betula, Cyperaceae

This subzone is characterised by a mixed detritus turfa deposit (Sh3, (As + Ag)1), consisting of organic material; plant fragments and root detritus, with silty clay and containing moderately frequent mica inclusions, (see Figures 39 and 40). LNE1/B consists of 6 samples; 192 – 186 cm, dating to approximately 4370 – 3820 Cal BP (Early Bronze Age).

Within subzone 1/B, there is an overall dominance in *Corylus-type* as the major pollen taxon which is present at approximately 20 - 40 % of TLP. Both *Betula* and *Alnus* are also high in frequency throughout this sub zone, *Betula* at 20 - 30% and *Alnus* at roughly 10-20% of TLP. A noticeable spike in Cyperaceae is seen at 192 cm, up to 30%, however it declines and maintains a percentage of 20% or lower. A fairly low, yet consistent percentage of *Quercus* is seen throughout the sub zone (5-10% TLP). In this subzone total tree pollen reaches the maximum abundance through the core accounting for 50 – 60% of TLP. LNE1/B suggests a fairly dense woodland with sedges presumed to be on the waterlogged marshy areas surrounding the loch edge. At 192 cm *Corylus-type* decreases and is overtaken by *Betula* at 30 % and Cyperaceae at 30 % TLP. This increase in arboreal pollen was soon overtaken again by *Corylus-type* at 40 % TLP, with Cyperacea pollen decreasing suddenly to 10 %. Poaceae is present in low proportions, but continuously through sub zone B, with a slight dip at 192 cm, where Cyperaceae increases, and then rising slightly at 187 cm. *Artemisia* and *Rumex* have a low average relative abundance in subzone 1/B, with small peaks in percentages of 1-5 % TLP.

Aquatics maintain a low level within LNE1/B. *Nymphaea* (Water-lily) is the dominant aquatic pollen within sub zone B, with only one small peak noted at 189 cm at 10%. A very small peak of *Typha angustifolia* (Narrowleaf cattail) at 3% and *Potamogeton* (Pondweed) at 2% was noted at a depth of 191 cm. Spores remain at low levels, with a peak of *Filicales* (Fern) at just under 10% at 191 cm. A decline in *Pteridium* (Bracken) is seen at the beginning of the sub zone from 10% to 1 -3%. *Equisetum* (Horsetail), *Polypodium* (Common Fern), *Sphagnum* (Peat moss) and *Isoetes* (Quillworts) are present in small percentages between 1-3% throughout sub zone. NPP levels remain fairly low, *HdV 18b Ascospore-type* is seen at 3% calculated against TLP, as well as infrequent levels of *HdV-55 Sordaria-type* (Fungi) at 2 %. Microcharcoal occurs at very low rates throughout the sub zone, with 7 fragments counted at 190 cm depth and 20 fragments counted at 186 cm.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type, Alnus, Betula, Quercus* with intermittent Cyperaceae, likely in the wetter areas closer to the loch edges. Some spore producers such as *Filicales* and *Pteridium* are likely to be found in low levels in the area, with *Nymphaea* also present at low levels within the loch. Low levels of charcoal indicate some burning in the catchment area, LNE1/B contains the highest amount of charcoal in the core. Pollen had poor preservation with high degradation and moderate total abundance with 87,000 to 301,000 pollen per cm^3, (see Figure 41) making the counting process more difficult in several samples, especially within sample at depth 192 cm. Fluctuations in water levels can attribute to the poor preservation of the pollen itself (Bercovici and Vellekoop, 2017) however, the loch is dominated by freshwater, so very minimal marine inundation is likely.

5.2.1.3 LNE1/C: 185 cm – 181 cm

Open Hazel/Alder/Birch/Quercus Woodland (*Corylus-type, Alnus, Betula, Quercus, Cyperaceae*)

The subzone is characterised by a mixed detritus turfa deposit (Sh3, (As + Ag)1), consisting of organic material; plant fragments and root detritus, containing moderately frequent mica inclusions (see Figures 39 and 40). LNE1/C consists of 5 samples; 185 – 181 cm, dating to approximately 3750 – 3560 Cal BP (Early – Mid Bronze Age).

Sub zone C sees a transition from the silt-clay-limus layer to herbaceous *detritus* peat by 184cm which then continues until the end of the core at 155 cm. LNE1/C demonstrates the beginning of the decline of tree pollen as the dominating sum of TLP with dramatic increases in shrub pollen at 185 cm to 40% and 183 cm to nearly 50% of TLP.

All tree pollen relative abundances appear to decline with an overall dip from 184 cm. A slight increase of tree pollen is seen before dipping again exiting the sub zone. *Betula* reduces from a 20% relative abundance to 10% by the end of the sub zone, similarly *Alnus* moves from 20% to finishing at 15% (both with the dip at 184 cm). *Quercus* is also at levels of 5-10% TLP, with a slight increase at the end of the subzone. There is a spike in herb pollen at 184 cm, predominantly Cyperaceae (10-25% TLP) and Poaceae (1-5% of TLP), which matches the decline of *Corylus-type.*

The relative abundance of aquatics reach their peak through the core in this subzone; a significant increase in most recorded aquatics. *Nymphaea* is the dominant aquatics pollen within LNE1/C, with approximately 5-18% relative abundance. Both *Potamogeton* and *Typha angustifolia* record fluctuating abundances with a peak of 5 – 10% at 184 cm.

Spores are consistently present, with *Filicales*, *Equisetum* and *Pteridium* as the main contributors, with between 5-10% abundance. NPP levels of *HdV Type 18b Ascospore* are seen, measuring to roughly 10 % and generally decreasing at 185 cm. Low levels of *HdV-55 Sordaria-type*, are also noted. Microcharcoal occurs at very low rates, 3 fragments were counted at 185 cm. No further charcoal was recovered from the core after 185 cm.

Based on the pollen spectra identified, LNE1/C is characterised by the highest proportion of tree pollen in comparison to all the other zones, this may reflect the densest woodland through the whole record. LNE1/C can be summarised as a wooded area of *Corylus-type, Alnus, Betula, Quercus,* with high peaks in Cyperaceae which was likely dominant in the wetter areas closer to the loch edges, *Nymphaea* present in loch but in decline, small spikes of *Potamogeton* and *Typha angustifolia* would have also been present in the loch. Patches of spore contributors; *Filicales*, *Equisetum* and *Pteridium* would have been growing at low levels in the area surrounding the loch. Low levels of charcoal indicate some burning in the catchment area. LNE1/C had poor to reasonable preservation in pollen, with moderate absolute abundance in counts, with a range in pollen ranging from 111,00 to 187,000 pollen per cm^3 (see Figure 41), making the counting process more time consuming in some samples.

5.2.2 LNE2: 180 cm – 164 cm

5.2.1.4 LNE2/A: 180 cm – 179 cm

Cyperaceae & Corylus-type

LNE2/A consists of a fibrous peat layer, containing plant fragments and contemporary moss roots (Th3, Sh1) (Figures 39 and 40). LNE2/A consists of 2 samples at 180 and 179 cm depth, dating to approximately 3490 Cal BP (Middle Bronze Age).

LNE2/A shows a dramatic drop in tree pollen and a move to a more open herb dominant wetland. Cyperaceae demonstrates a sharp spike in TLP, increasing to 55% through this subzone overtaking all other land pollen, whilst other herb pollen maintain low levels at roughly 1-5%.

Shrubs (predominantly *Corylus-type*) show a decline to 25% TLP at 180 cm, all tree pollen also show a similar dip at 180 cm. *Betula* decreases from a 15% TLP to a dip of 5% at the end of the sub zone. Similarly, *Alnus* declines from just below 20% TLP to its lowest of 5% at 180 cm.

Aquatics are present at similar levels of cover to Tree pollen throughout this zone. A decline of *Nymphaea* from roughly 18% to 2% of cover is seen within the sub zone, whilst *Typha angustifolia* and *Potamogeton* display an increase in cover from 2% to 5-10%. Spores show a dominance in *Pteridium*, but still at low levels of approximately 2-5% cover. All of the spore pollen show a similar dip at 180 cm that appears to affect Tree and Shrub pollen. NPP levels are very low, *HdV Type 18b Ascospore, HdV-55 Sordaria-type* and *Venturia inaequalis* (Fungi) are seen with 1-2% counts.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as a clear reduction in tree pollen and *Corylus-type*, with an increase in herbs, sedges in particular. Perhaps indicating some thinning or opening up of the woodland canopy. *Nymphaea present in loch but in decline.* Patches of *Equisetum* would have been present but declining throughout subzone. LNE2/A pollen had poor to reasonable preservation with moderate to high frequency in counts, with a range in pollen ranging from 198,000 to 262,000 pollen per cm^3 (see Figure 41).

5.2.2.1 LNE2/B: 178 cm – 175 cm

Corylus-type & Cyperaceae

LNE2/B consists of a fibrous peat layer, containing plant fragments and contemporary moss roots (Th3, Sh1) (see Figures 39 and 40). The subzone contains 4 samples; 178 – 175 cm, dating to approximately 3420 – 3340 Cal BP (Middle Bronze Age).

LNE2/B is characterised by the decline in herb dominance as shrubs begin to increase in relative abundance once more. Cyperacea begins a fairly rapid decline to 25% TLP and then finishing sub zone with roughly 12% TLP. Corresponding dips in *Betula* are seen moving from 20 % TLP at 178 cm to 2 % at the end of the sub zone. Decreases in Tree and Herb pollen are matched with increases of Shrub pollen. *Corylus-type* begins a noticeable rise in percentage from 30 % TLP to 80 % TLP coverage. A slight dip in *Corylus-type* at 177 cm is mirrored by a slight rise in Poaceae to 10 % and Cyperaceae to 30 % TLP.

LNE2/B shows a generally low but persistent percentage of Aquatic pollen. A peak in *Typha* a*ngustifolia* is noted at 178 cm of 10 %, which is the dominant aquatic pollen. *Potamogeton* pollen appears as a consistent trend throughout sub zone at percentages of 1-3%. A general trend of decline is seen within LNE2/B. Spores maintain a fairly low percentage within LNE2/B, the presence of *Pteridium* and *Filicales* are seen at a fairly constant level of 2- 5 %. NPP levels are very low, *HdV-55 Sordaria-type* was recorded at peak levels of 5 % in relation to TLP.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type,* with some *Betula* woodland, a slight decline in Cyperaceae growing in landscape, *Typha* a*ngustifolia* dominant aquatic. LNE2/B pollen had poor to reasonable preservation with fairly high frequency in counts, with a large range in pollen absolute abundance from 130,000 to 564,000 pollen per cm^3 (see Figure 41), making the counting process fairly easy throughout LNE2/B.

5.2.2.2 LNE2/C: 174 cm – 170 cm

Corylus-type & Cyperaceae

LNE2/C consists of a fibrous peat layer, containing plant fragments and contemporary moss roots (Th3, Sh1), (Figures 39 and 40). The subzone contains 5 samples; 174 – 170 cm, dating to approximately 3290 – 3240 Cal BP (Middle Bronze Age).

LNE2/C is characterised by a decline in Shrub pollen, with *Corylus-type* declining rapidly from 80% to 50% TLP by 174 cm. The overall percentage of *Corylus-type* is still high throughout the sub zone, indicating that coverage would still be fairly consistent. Subzone LNE2/C shows a gradual rise in

Cyperaceae from 10-30% TLP, a spike in *Galium* (Bedstraw) is also noted as 15% at 172 cm, which is prominent in comparison to all other zones.

The relative abundance of tree pollen shows some variability, especially in *Betula*, which is noted at 20 % before dipping to 2 % at 172 cm before rising again at 170 cm. There is also a gradual increase of *Alnus* from 2-15 % TLP. Tree pollen is generally low in this sub zone in comparison to Shrub and Herb pollen.

Aquatics present a fairly low percentage of pollen, *Typha Angustifolia* and *Potamogeton* show slight peaks at 174 cm of 2-5%, although they both decline at 172 cm where *Galium* peaks. A large increase of *Equisetum* is seen towards the end of sub zoneLNE2/C, noted at 30 % coverage and showing the first rise in spore pollen to such a high percentage. *Sphagnum* relative abundance increases to a peak of 10% at 173 cm. NPP levels are very low, *HdV-55 Sordaria-type* was recorded at peak levels of 2% counts.

Based on the pollen spectra identified within LNE2/C the interpretation of the environment of deposition can be summarised as a slight decrease in woodland cover density, some open wooded areas of *Corylus-type* and *Alnus,* with arboreal pollen increasing, LNE2/C indicates relatively high abundance in herbs likely due to the increased clearing. Cyperaceae which was likely dominant in the wetter areas closer to the loch edges, but has more space to flourish. A spike in *Galium* pollen and *Equisetum* spores also represents a fairly herb and shrub dominant environment with patches of *Equisetum* and *Sphagnum* in the areas. Patches of *Equisetum* would have been present but declining throughout subzone. LNE2/C pollen had poor to reasonable preservation with fairly high sparsity in counts, with a large range in pollen ranging from 44,000 to 275,000 pollen per cm^3 (see Figure 41), making the counting process more difficult in some samples, especially sample taken from 171cm depth.

5.2.2.3 LNE2/D: 169 cm – 167 cm

***Corylus-type* dominant**

LNE2/D consists of a fibrous peat layer, containing with plant fragments and contemporary moss roots (Th3, Sh1), (see Figures 39 and 40). The subzone contains 3 samples at depths 169 – 167 cm, dating to approximately 3180 – 3130 Cal BP (Middle – Late Bronze Age).

The data presents a fairly rapid change in vegetation, an increase in *Corylus-type* as the dominant taxon is seen from the start for LNE2/D, an increase in relative abundance from 45 to 80% demonstrate this. A gradual decline in both Tree and Herb pollen is seen in the sub zone. *Alnus* and *Betula* being the major tree pollen, both show generally declining trends but beginning a small increase in *Betula* to 15% at 166 cm in the next zone. The dominant herb pollen in LNE2/D is Cyperaceae, which has a gradual decline from 30% at the beginning of the sub zone, to 20% at the end.

Aquatics are generally low throughout, with *Potamogeton* and *Myriophyllum alterniflorum* showing low counts of 1-2%. Spores begin a decline of the dominant spore taxon *Equisetum*, from 25-2% throughout sub zone. Very low NPP levels are seen within sub zone, *HdV Type 18b Ascospore* and *HdV-55 Sordaria-type*, measuring to 1%.

Based on the pollen spectra identified within LNE2/D the interpretation of the environment of deposition can be summarised as a move to a more wooded area of *Corylus-type,* with some peaks of *Alnus.* Cyperaceae is also present but declining due to the slightly decreased canopy from an increased density of woodland. Patches of *Equisetum* would have been present but declining throughout subzone. LNE2/D pollen had poor to reasonable preservation with fairly high sparsity in counts, with a range of 106,000 to 195,000 pollen per cm^3 (see Figure 41), making the counting process more difficult in some samples.

5.2.3 LNE3: 166 cm – 161 cm

Corylus-type dominant

LNE3 consists of a fibrous peat layer, with plant fragments and contemporary moss roots (Th3, Sh1), (Figures 39 and 40). The zone contains 6 samples; 166 – 161 cm, dating to approximately 3080 – 2980 Cal BP (Late Bronze Age).

LNE3 is characterised by a high proportion of shrubs, with a gradual increase in herbs towards the end of the zone. *Corylus-type* is the dominant taxon for LNE3, starting with a relative abundance of 78% TLP and undulating with slight dips and peaks. Cyperaceae shows a gradual increase throughout LNE3. Trees and aquatics appear fairly low with some small peaks, *Betula* dips from 10% TLP at 166cm to approximately 2% at 164cm. Similarly, *Alnus* shows a small peak of 10% TLP at 162 cm, but maintaining a consistently low abundance for the rest of the zone. Aquatics do not present any notable trends besides an overall low count. Collectively, spores are present in low abundances, <4% TLP. LNE3 displays NPP levels at the highest seen within the core, *HdV Type 18b Ascospore* peaks at 20% TLP. *HdV-55 Sordaria-type* and *Venturia inaequalis* are seen with 1-2%.

Based on the pollen spectra identified within this LNE3, this zone represents the maximum dominance of *Corylus-type,* hence is likely to be an open shrub dominated hazel woodland with some birch and alder. High levels of *HdV Type 18b Ascospore* suggests *Eriophorum* was present (Miola, 2012, van Geel, 1978). LNE3 pollen had reasonable preservation and moderate sparsity, with a range of 120,000 to 245,000 pollen per cm^3 (see Figure 41), making the counting process more difficult in some samples.

5.2.4 LNE4: 160 cm – 155 cm

***Corylus-type*, Betula & Cyperaceae dominant**

LNE4 consists of a fibrous peat layer, with plant fragments and contemporary moss roots (Th3, Sh1), (Figures 39 and 40). There was some damage to the top of the core, meaning 155 cm was the last sample taken. The zone contains 6 samples; 160 - 155 cm dating to approximately 2920 – 2810 Cal BP (Late Bronze Age)

LNE4 is characterised by a decline in *Corylus-type*, moving from 35% TLP at its peak, to 20% at 155 cm. Other shrub species stay consistently low throughout LNE4. An increase in Cyperaceae to 50% shows the final phase of the core as an herb dominant environment. A small peak in *Rumex* (Dock) is seen at 158 cm (10 % TLP), noted as the highest recorded count of this pollen taxon throughout the core. Tree pollen maintains a fairly low percentage of TLP in LNE4, with the exception of *Betula*, that shows some variability with peaks between 15-25 %, its highest recorded count for several zones.

Aquatics maintain a very low count with no apparent trends. The abundance of *Filicales* (13%) and *Sphagnum* (10%) is measured at 155 cm depth. *Equisetum* has a relatively high abundance (up to 35%) then declines to approximately 2% by the top of the zone, the highest recorded for this spore. NPP levels decrease from the previous zone, *HdV-55 Sordaria-type* peaks at 155cm with 5%, *HdV Type 18b Ascospore,* appearing frequently at approximately 5-7%.

Based on the pollen spectra identified within this LNE4, this zone appears to be characterised by a general decrease in tree and shrub pollen as herbs increase, suggesting a slightly more open woodland canopy, still dominated by hazel, but with some periods of increased birch, alder and oak. There is a rise in *Equisetum* spores at the start of the zone indicating an increase in ferns. LNE4 was noted as being one of the sparsest zones in pollen and concentrations, ranging of 62,000 to 290,000 pollen per cm^3 (see Figure 41), with poor preservation of pollen grains. Possible fluctuations in water drainage may have contributed to issues with palynological survival, or attributed to the poor preservation of the pollen itself (Bercovici and Vellekoop, 2017).

5.3 Summary of data

Trees have their highest relative abundance early on (zones LNE1 A-C) dominating the pollen assemblages with 30 – 50% of TLP (Figure 39). Shrubs are also abundant throughout, but tend to increase to dominate the pollen assemblages from zones LNE2/B and then LNE2/D onwards. Herbs tend to be a high variable through the sequence with relatively short periods of dominance. There are a few notable rises in herb pollen peaking at 60 % abundance at the top of core in LNE4 at 155 cm, and LNE2/A at 180 cm. It appears that Cyperacea, which is the most dominant herb, followed by G*alium*.

Shrubs, as discussed above, appear to be largely linked to the increases and decreases of herb pollen. Shrub pollen, mainly *Corylus-type*, appears to have a noticeable rise to 80 % of vegetation cover in LNE3, at 164 cm. There is another peak in LNE2/B at 176 cm. LNE1/A presents two smaller peaks at 197 cm and 199 cm with shrubs making up 46-48 % of the vegetational cover.

Tree pollen appears to be noticeably low throughout Zones 2 and 3, there appears to be some peaks within Zone 4 which correlates to shrubs, Zone 1 presents a fairly stable percentage of tree cover from 30-55 % vegetation cover. *Betula* and *Alnus* are shown as being the most dominant tree pollen throughout the core. As discussed above, when tree pollen is high, it appears that shrub pollen is at a lower percentage.

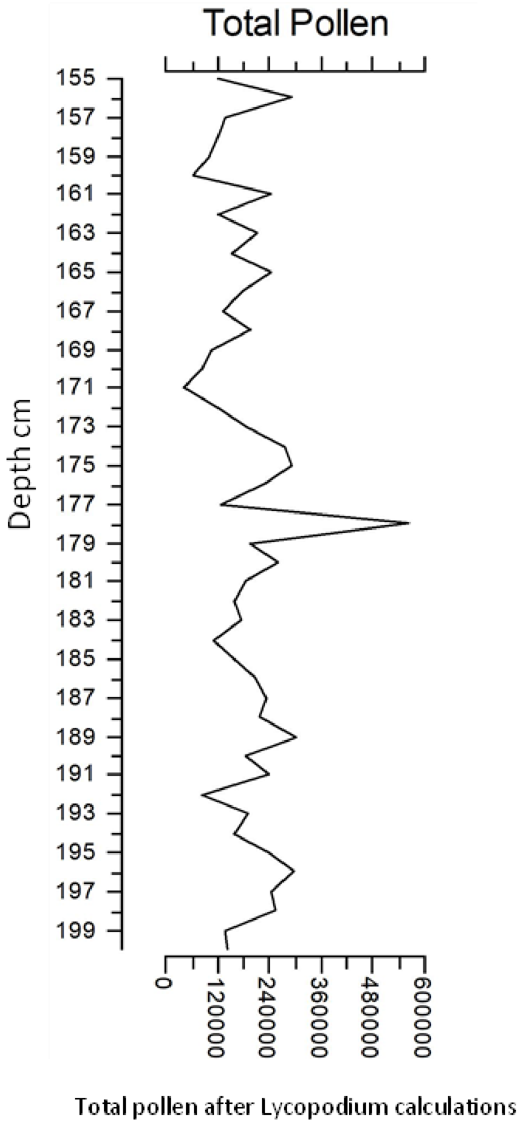


Figure 41 Total pollen sedimentation rates expressed as grains per cm², indicating abundance rates, plotted against depth of core LNE97/1 in cm.

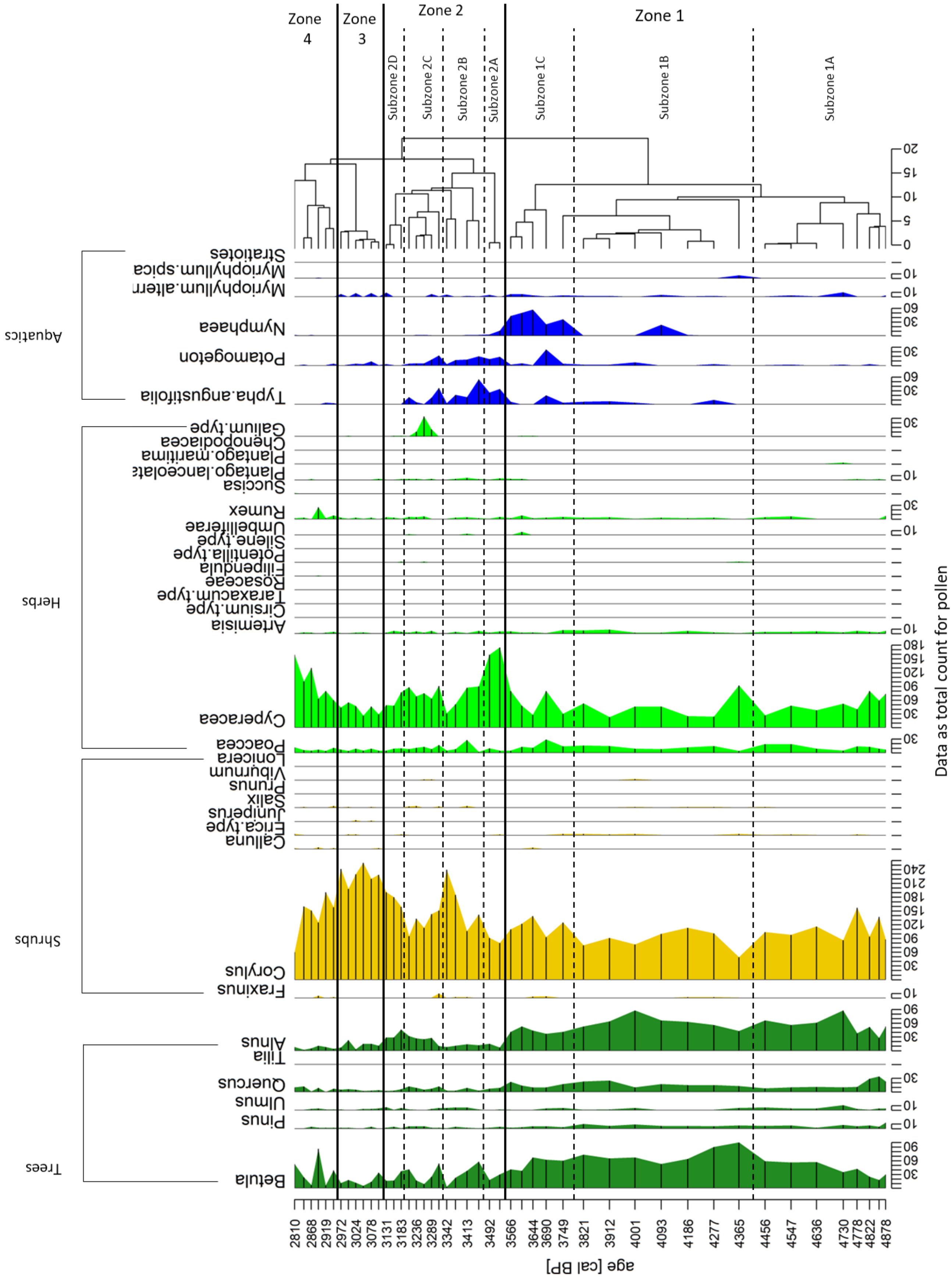


Figure 42 Age vs Depth model of total pollen counts from core LNE97-1 processed using Bchron package (see Haslett and Parnell, 2008). Black lines indicate pollen zones identified based on stratigraphically constrained cluster analysis (CONISS) using Rioja (see Juggins, 2020), dashed lines indicate sub-zones identified based on qualitative trends in pollen spectra.

6.0 Interpretation and Discussion

6.1 Interpretation and palaeoenvironmental reconstruction

The palynological data presented suggests there are some clear environmental changes occurring throughout the core. The calibrated ^{14}C dates collected from 196 cm to 155 cm suggest a period of approximately 1854 - 2057 years (see Figure 35, 36 and 42), dating from the Late Neolithic to late Bronze Age. This chapter is broken down into the different phases appearing within the core to allow a clear and concise discussion. Within the discussion, the *Corylus-type / Myrica* curve is referred to as *Corylus-type*, due to the low levels of *Myrica* found in the previous pollen record at Loch nan Eala by Shennan *et al.* (1994), although this interpretation does not mean it was absent from the area (Edwards, 1981).

6.1.1 LNE1/A

4878 – 4456 Cal BP (Late Neolithic – Early Bronze Age)

The overall vegetation pattern within LNE1/A indicates that trees and shrubs tend to co-dominate, with shrubs being more common earlier in the subzone (from 4878 to 4778 Cal BP) then trees becoming more common later in the subzone (see Figure 39 and 42). A high relative abundance in *Alnus* and *Corylus-type* throughout the subzone suggest that the major fluctuations in tree and herb pollen may be related to environmental factors as it is argued that *Alnus* is not a successful competitor (see Chambers and Elliott, 1989), therefore only in a reduction in the number of competitors by the clearance of other tree species, would allow reestablishment.

During the time period covered by LNE1/A, the basin would likely be subject to influxes of tidal currents as Shennan *et al.* (1994) demonstrate the hydrological isolation of the main basin from marine contact at 3745 ± 50 Cal BP, with final exclusion from marine surges and tides in 3440 ± 50 Cal BP. LNE1/A (4878 – 4456 Cal BP), demonstrates that the final isolation from sea-water influx had not occurred at this period in time. Salinity of the Loch within subzone A would likely have been brackish from tidal influxes mixing with gathering freshwater. However, the relatively low proportion of *Plantago maritima* (Sea Plantain) with highest levels at 1% at 4730 Cal BP, and a more prevalent occurrence of *Myriophyllum alterniflorum* at 3%, (which has a low salt tolerance, Preston and Croft, 1997) suggests that basin salinity must have been low at this time, but an environment in which plants with low salt tolerances can exist.

Corylus-type is the dominant pollen within this subzone with 30 – 50% of TLP, there are two peaks in abundance at 4822 Cal BP and 4778 Cal BP. *Corylus-type*, like much of the shrub and tree pollen is likely growing around the edges of the loch or in the catchment area of Loch nan Eala. As *Corylus-type* can grow in varied shades, is it a perfect contender for a varied growing location in the basin, it prefers moist soil and can tolerate strong winds but not maritime exposure (Rackham, 1980), perhaps suggesting the slight dips in its pollen count may represent its peripheral growth away from the loch edge and periodic increases in salinity due to sudden high tides and/or storm flooding. Although, as there is little evidence of salt tolerant vegetation in and around the basin, the general salinity must maintain reasonably low to very low levels. Western Scotland has a specialised hazel woodland, with almost no other trees or shrubs present, that has been mostly unaffected by human management throughout the Holocene, unique to coastal western Scotland (Copping and Copping, 2003). It is quite rare, but Loch nan Eala is located in this area and this concept could be relevant to hazel dominance. The herb, Cyperaceae*,* is present in relatively high proportions throughout LNE1/A ranging from 10-25%, indicating a wetter environment surrounding the loch. However, pollen grains are usually only identified to genus or family level, meaning that it may be problematic when different species in the same genus have contrasting affinities (Walker and Lowe, 1997). Without strong identifiable evidence to suggest the species of sedge, it is often necessary to pair with macrofossil data or non-pollen palynomorphs to present a truer representation of the environmental record. NPP data was limited within the investigation, however small percentages of NPP *HdV-18b* were seen within LNE1 subzone A. NPP *HdV-18b* tends to relate to *Eriophorum* and the Cyperaceae curve with *Eriophorum* macros tending to be common, but often does not survive in the pollen record (Miola, 2012, van Geel, 1978). *Eriophorum* is a particular type of Cyperaceae which is a signifier of a wetland dominant sedge that prefers boggy conditions (Preston and Croft, 1997), the presence in LNE1/A shows wet conditions and a move to a boggier environment.

A clear dip in *Quercus* pollen is evident at 4778 Cal BP. The relative abundance then remains low through the rest of this subzone. Shennan *et al*. (1994) notes low levels of human impact at Loch nan Eala, although the main focus of the study was investigation of sea-level changes, so it can be argued that small scale changes may be more visible in this fine resolution study of the core. The small changes that are seen in vegetation may be a reflection of small-scale management related to forest management and low shrub vegetation may relate to grazing.

Low quantities of (microscopic) charcoal fragments were noted within subzone 1A, (see Figure 40), which may be the result of naturally occurring fires in the surrounding area or may be related to smaller scale human activity. Due to very low counts, it is unlikely that controlled burning was occurring at Loch nan Eala as fires produce large amounts of charcoal (Patterson *et al.,* 1987;

Edwards and Whittington, 2000; Edwards *et al.,* 2000; Dodgshon and Olsson, 2006; Froyd, 2006; Grant *et al.,* 2014).

Within this subzone, it appears that there is an increase in tree pollen largely driven by *Alnus* and *Betula*. Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type, Alnus, Betula, Quercus* with intermittent Cyperaceae, likely in the wetter areas closer to the loch edges. Low levels of charcoal indicate some burning in the catchment area within LNE1/A, this may be related to anthropogenic events such as controlled burning and hearths or naturally occurring burning events such as lightning or wild fires. The changes within this subzone are likely to be due to more natural and climatic forcing rather than due to human impact.

At other sites in northern Scotland, the major woodland decline of *Pinus* and *Betula* has been seen to be around this period, with sites such as Suisgill, in Kinbrace, dating the decline to 5435-4831 Cal BP (Andrews *et al*., 1985). Within LNE1/A, we do see a slight dip in *Pinus* and *Betula,* perhaps signifying a regional decrease in some arboreal pollen. The cause of this decrease at Suisgill, has been speculated as being a combination of Neolithic clearances and hydrologically or climatology induced variations in the wetness of blanket bog (Andrews *et al*., 1985).

Within the broader area there are a few recorded sites which may compare to a similar Late Neolithic period found within LNE1/A, although comparable data is fairly low. Canna, Beinn Tighe, located on the small isles west of Arisaig (see Tables 1 and 2), possible Neolithic pottery was found at a mound site, although the pottery was found out of context and cannot be used to date the mound (Archaeological Data Service, 2022, Canmore, 2022). Located to the north of Arisaig, a possible Neolithic henge monument was found at Portree, Home Farm on the Isle of Skye, (see Table 2), although the site was artefact poor and the only datable pottery was dated to late Bronze Age (Suddaby, 2007), to the north west of Glasgow, a possible Late Neolithic – Bronze Age burnt mound was found containing fire cracked stone and lithics at Uamh MhÓr in Cove, although ^{14}C dating results are still pending (Piper *et al*., 2020) (see Table 4). On the isle of Islay, an occupation site was found at Coultorsay, containing fragments of possible Neolithic and Iron Age pottery sherds (Kilpatrick, 2017) (see Table 4). Investigations at Kingarth Quarry on the Isle of Bute revealed possible Neolithic ring ditch structures and artefacts likely being associated with prehistoric activity, although the date and purpose of the features remain enigmatic according to the watching brief results (Mitchell and O'Connell, 2005) (see Table 4). Collective data from archaeological records from the investigation of several sites listed above suggests that there is a Neolithic presence within the western area of Scotland. Interestingly, we are seeing a movement from the mainland to the isles surrounding Arisaig, highlighting the adaptability and flexibility of these people to travel and survive in harsh locations.

6.1.2 LNE1/B

4365 – 3821 Cal BP (Early Bronze Age)

LNE1/B subzone begins to see a gradual increase in total tree pollen in comparison to LNE1/A, with tree pollen dominating the pollen spectra throughout this zone at 40-55% TLP (see Figures 39 and 42), there is a noticeable peak at 4365 Cal BP in *Betula* and a peak in *Alnus* at 4001 Cal BP. LNE1/B appears to show influxes in tree pollen with *Betula* and *Alnus* the most abundant species acting as strong competitors against *Corylus-type* throughout, with some dips in *Alnus* and *Corylus-type* when *Betula* and Cyperaceae peak at 4365 Cal BP. These dips and peaks may be related to the competition for canopy space and light rather than any human interference as *Alnus* is thought to be a rapid seed producer into open sites, however, seedlings are very shade and drought sensitive, so woodland regeneration is often poor (Hodgson *et al*. 1995, Grime *et al*. 19996). The beginning of LNE1/B falls into the climatic cold peak referred to as the 4.2 ka event (Bond *et* al, 2001), dating to around 4200 Cal BP, it could be suggested that the dips in *Alnus* and Cyperaceae may be related to this sudden decrease in temperature. The 4.2 ka event is recorded as a shift to cooler but also wetter conditions in the British Isles, with sea-surface temperatures dropping 1-1.5°C (Bond *et al.,* 2001; Barber and Charman, 2003; Davis *et al.,* 2003; Mauquoy *et al.,* 2008; Charman, 2010). However, as Sybenga (2020) suggests, the increase in precipitation would have been beneficial to *Alnus* and Cyperaceae, and records show that these species do not appear affected by the sudden cooler climate of the 4.2 Ka event. We do see an increase in *Alnus* pollen especially at 4001 Cal BP, likely thriving during this time of increased precipitation. It has been suggested that by 3950 Cal BP summer temperatures were 1°C warmer (Davis *et al*., 2003) which may have encouraged the peak in *Quercus* pollen at a similar time, although there is complexity in establishing what distinguished the 4.2 ka event in the British Isles (Roland *et al*., 2012).

Interestingly, the 4.2 ka event appears to have negatively affected *Pinus* across the northern British Isles, with the increased wetness impacting *Pinus* growing rates (Birks, 1975; Bennett, 1984, 1995, Gear and Huntley, 1991, Blackford *et al*., 1992, Hall *et al*., 1993, Smith, 1996, Willis *et al*., 1998, Tipping *et al.,* 2008b). At Loch nan Eala, we do not see a large dip in *Pinus* pollen, although it is at very low levels, it appears to continue at a fairly steady percentage. Other sites located in northern Scotland mark the decline of *Pinus* at 4450 Cal BP at Braehour, 4140 Cal BP at Rowens, and 3810 Cal BP in Dalchork (Sybenga, 2020), showing there is regional variation. Evidence available indicates a long period of regional pine colonization, followed by a widespread demise in Scotland at approximately 4000 Cal BP (Bridge *et* al., 1990). Declining pine values at this time have been recorded as the ‘pine decline’ (Peglar, 1979, Bennett, 1984, Blackford *et al*., 1992, Charman *et al*., 1995, Smith, 1996, Huntley *et al.,* 1997, Tipping *et al.,* 2008b), although there has been speculation regarding whether it was the result of climatic events or the result of human activity (Birks, 1993, Tipping, 1994, Tipping *et al.,* 2008b).

Small peaks of aquatic pollen are seen throughout the LNE1/B, but may just represent changes in water levels of the loch. Lower levels of variations in silt are seen within LNE1/B in comparison to LNE1/A, as mica is thought to be sourced from tidal currents washing into the basin, the decrease may also suggest that the basin is more isolated than in LNE1/A (see Appendix, Table 5). The slight increase in aquatics also supports the interpretation of a more isolated basin than in LNE1/A, as suggested by Shennan *et al*. (1994), although Mica inclusions suggest final isolation of the main basin was not yet complete. which was published in Shennan *et al.* (1994) indicate isolation from marine influence was seen in cores LNE29 at 3600 Cal BP, LNE1 at 3440±50 BP and LNE16 which has a date of 3745±50 BP they contained consistent *Plantago lanceolata* and diatoms indicating isolation at that date.

Very low percentages of *Plantago maritima* can be seen within the lower layers of the LNE1/B (see Figure 40), which is likely connected to marine tidal influxes. The environment within the loch would likely be variable with the fluctuation of salinity produced by tidal flooding, the salt tolerance of vegetation surrounding Loch nan Eala would change the dominance of certain species. Low levels of NPP *Eriophorum* HdV 18b and indeterminate algae were noted within LNE1/ B, which may suggest there were periods of wetter boggier conditions surrounding the loch, perhaps with some water level increases allowing more wet tolerant species to thrive, especially at 4365 Cal BP.

Low quantities of charcoal fragments were noted within LNE1/ B (see Figure 40). The low charcoal count suggest that it is unlikely that large amounts of burning was happening at the loch edge, but perhaps more random natural burning events in the catchment area. It could also relate to smaller scale human activity or perhaps domestic fires in the catchment area or perhaps even relating to the crannog, although it is unclear what the true reason was that created the fire. Coprophilous fungal spores (CFS) such as *Sordaria-type* (*HdV 55-A*) were seen within LNE1/B (see Figure 40), *Sordaria-type* (*HdV 55-A*) is a fungal taxon that may be related to dung but also associated with general decomposition. As *Sordaria-type* (*HdV 55-A*) cannot be used to wholly identify grazing animals, the presence of *Sporormiella* would provide stronger evidence for an obligate dung fungus (van Geel, 1978, van Geel *et al*., 1983b, van Geel *et al.,* 2003, Baker *et al.,* 2013), although none was identified within this core.

It is important for CFS evidence to be paired with evidence within the pollen record as a complimentary factor for interpreting palynological evidence, CFS data may be unreliable in isolated interpretation, especially regarding presence of small-scale agricultural activity (Davies, 2019). Species such as *Artemisia* (genus in the Aster family), a nitrophilous species often related to nutrient rich areas including habitations and cultivated/farmlands, as well as coastal influence (Ding *et al.,* 2011). *Artemisia* was noted at low but persistent levels throughout LNE1/B, this may be paired with the CFS evidence.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type, Alnus, Betula, Quercus* with intermittent Cyperaceae, especially at the beginning of LNE1/B, which was likely dominant in the wetter areas closer to the loch edges. The dip in *Corylus-type* at 4365 Cal BP could be a sign of browsing animals, eating new shoots, the low fluctuating levels of *Artemisia* and NPP *Sordaria-type* (*HdV 55-A*) throughout LNE1/B may also tie in with the idea that land was being used for anthropogenic purposes.

Datable archaeological evidence was found within the vicinity of Loch nan Eala (see Tables 1 and 2), located in Arisaig to the north-west of the core LNE97/1, a kerb cairn with the remains of a robbed-out cist was identified with a concentration of burnt bone from a single individual, thought to be a separate burial, identified 3 m from the cist (Carter *et al.*, 2005, see Table 1), ^{14}C dating from burnt human bone revealed the date of 4090 – 3830 Cal BP (Carter *et al.,* 2005), which ties in with the dating of LNE1/B. Another 3-4 cairns and a ring ditch were identified in the Arisaig area which were thought to be Bronze Age in date (see Table 1 to 4 and Carter *et al*., 2005), although a lack of datable evidence means there is no definitive answer to whether they were built within this timeframe. As mentioned in LNE1/A, there are a small number of sites in the more regional area that may be used as comparable evidence for human activity within this time period, sites which may share dating to LNE1/B are Uamh MhÓr in Cove, Home Farm in Portree (Isle of Skye) and Coultorsay on Islay. To the west of Glasgow, on the Isle of Arran, at Lamlash, Arran Highschool, the remains of a Bronze Age cist cemetery was found with associated datable finds (Rees and Shaw, 2004a, Shaw, 2005) (see Table 4), although dating was mainly through pottery typology as no ^{14}C dates were taken from the site. From the archaeology to date, western Scotland is seeing a greater number of excavated sites relating to the Bronze Age than in the Neolithic. The sites are mainly taking the form of positive, impact-heavy features, which begin shaping the landscape in the form of cairns and cemeteries. The kerb cairn located to the north-west of Loch nan Eala which has provided ^{14}C dates from burnt human bones located near to the cist, has shown that a range of different practices was taking place in this subzone, funerary practices and attitudes towards the dead can be seen for the first time in the Arisaig area, showing the signs of more sedentary peoples.

A human tooth found in the midden at Sand, Wester Ross, dating to 3990–3680 Cal BP belonged to an individual aged four to eight who had a twenty percent marine diet (Schulting, 2009), perhaps we can use this evidence as a sign that marine diets may have been eaten during this period, as it is thought that Early Bronze Age diets were overwhelmingly terrestrial, with little or no use of marine resources despite the availability to coastal populations (Parker Pearson *et al.,* 2019, Curtis and Wilkin, 2019). It is likely that a combined diet which did not solely rely on marine foods occurred in the Arisaig area, with a higher reliance on terrestrial animals and grains, although further evidence for this is needed. The archaeological evidence provided for this period allows for a greater overview of what was happening in the area at this time, changes in funerary and construction as well as theories on diet may further indicate that the changes in vegetation in the catchment area could in fact by linked to anthropogenic activities.

6.1.3 LNE1/C

3749 – 3556 Cal BP (Early – Mid Bronze Age)

LNE1/C begins to see the first prominent decline of arboreal pollen with fairly low levels of herb pollen and consistently moderate levels of *Corylus-type* pollen. There is a peak in aquatic pollen within this subzone, although this will not likely give insights into climatic or environmental pressures at the time. A notable decrease at approximately 3690 to 3566 Cal BP is seen in all tree pollen, with some later peaks potentially indicating regeneration. *Corylus-type* pollen and the dominant aquatic pollen *Nymphaea*, herb pollen such as Cyperaceae and Poaceae increase as well as spikes in *Potamogeton* and *Typha angustifolia* indicate a change in environment to a more open canopy. Small spikes in *Artemisia,* Umbelliferae and *Rumex* are also present within LNE1/C, which may be related to small scale human activity. The opening up of the canopy due to decrease in relative abundance of tree pollen, would allow for herb pollen proportions to increase, perhaps we are seeing more activity from human impact and also rejuvenation of herb species following deforestation and grazing activities. The sudden drop in tree and *Corylus-type* pollen may be the result of environmental changes or from human impact with animals grazing the new saplings and producing a wider canopy space for plants such as Poaceae*, Artemisia,* Umbelliferae*, Rumex* and Cyperaceae to thrive with more sunlight and space. At around 3500 Cal BP, towards the end of LNE1/C there is a recorded shift in climate towards a period of increased precipitation (Charman, 2010, Sybenga, 2020), perhaps attributing to the further increase of wetter favouring vegetation such as some Cyperaceae types.

Some of the highest levels of *Pteridium* spores are seen within LNE1/C, *Pteridium* (bracken) was a useful plant used by humans for multiple purposes, it is unclear whether it was a resource used locally by the people at the time. The earliest evidence of *Pteridium* use was found in a Neolithic long barrow, near Avebury, Wiltshire, where it was suggested that both burnt bracken and unburnt bracken were brought in from elsewhere and used as fertiliser on the cultivation plot with the unburnt bracken forming a component of re-deposited occupation debris (Ashbee *et al.,* 1979). Bracken pinnules were also recovered from a Middle to Late Bronze Age midden deposit at Potterne in Wiltshire, where it was thought that *Pterdium* remains may have come from animal bedding or fodder thrown onto the midden, although it is unclear whether bracken may have grown on the midden itself and been preserved in situ (Carruthers, 2000, Straker 2000). *Pterdium* is however, a toxic plant for browsing or grazing animals to eat, but can also cause issues when animals eat contaminated hay infected with bracken fern pathogens, thiaminases and antithiamine factors can cause bracken fern poisoning (Stegelmeier et al., 2013). Most *Pterdium* intoxications affect grazing livestock and wildlife, however, human and companion animal poisoning also occurs due to plant or toxin contamination of prepared feeds, food, medicines, and herbal products (Stegelmeier *et al*., 2013).

NPP *Arnium - type HdV 261/262* and *Sordaria-type HdV 55-A* were noted at low percentages throughout LNE1/C (see Figure 40), it may be indicative of grazing activity when combined with other CFS evidence, but may also relate to general decomposition (van Geel, 1978, van Geel *et al.,* 1983b, van Geel *et al*., 2003, Baker *et al.,* 2013). NPPs are present around 3749 to 3566 Cal BP and may be associated with animal dung from gazing animals or non-domesticated animals browsing the area (Davies, 2019). The sudden decline after this time may show that areas were successfully grazed and herbs diminished, the lack of animal related NPP spores may also indicate a move to regeneration of the area, that would be if the NPPs do indeed relate to CFS and not to general decomposition.

Small amounts of microcharcoal were recorded in LNE1/ C (see Figure 40), which may relate to human activity in the local vicinity. The small proportion may suggest that burning activities were not impacting the direct environment around where the core was taken, but perhaps in the wider catchment area. Burning may also be connected to the undated Crannog located southeast of the core and loch water carried the fragments to the sample site. It is likely that the charcoal would be contemporaneous with the pollen grains counted, as movement of the charcoal through air or water would not cause much delay in a small catchment.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type, Alnus, Betula, Quercus,* with high peaks in Cyperaceae which was likely dominant in the wetter areas closer to the loch edges, aquatics were recorded at their highest within the core. As discussed in LNE1/B, this subzone may relate to previously listed archaeological sites, however, as the Bronze Age sites mentioned above do not appear to have ^{14}C data yet to provide a more specific date. It is mentioned that the roundhouse at Home Farm in Portree, Isle of Skye, provided very small frequencies of cereal grain evidence dating possibly to the Middle Bronze Age (see Suddaby, 2007). The roundhouse itself is thought to be non-domestic (Suddaby, 2007), making it a not particularly good choice as a representative for cereal production in the western highlands. There is clear evidence from archaeological sites, cereal data and changes in the environmental record suggesting a range of anthropogenic activities occurring at this period of time.

6.1.4 LNE2/A

3492 Cal BP (Middle Bronze Age)

The decline in arboreal pollen is seen most dramatically around 3492 Cal BP at the transition to LNE2/A. *Alnus, Betula* and *Quercus* pollen all decline indicating that a change is occurring at this time. Environmental factors may be the cause of the sudden dip in multiple species, colder climates and higher rainfall can all cause a sudden change in environmental conditions affecting vegetation cover. Even environmental factors such as late frosts can impact tree growth and kill young trees, especially *Quercus* which is vulnerable to sudden changes in temperature (Thomas, 2000). A decline in woodland has been seen throughout the north and west of Scotland particularly in the Late Neolithic to Middle Bronze Age as mentioned previously (Gear and Huntley, 1991, Tipping, 1994, Tipping and Tisdall, 2004, Tipping *et al.*, 2008a). However, work from Carter *et al*. (2005), Clarke (2000), Shennan *et al*. (1994, 1995) and Williams (1977) show that unlike most areas in Scotland, Arisaig has no major marked decline in woodland in quantitative comparisons to its regional counterparts at this time (Carter *et al*., 2005). Sybenga (2020) suggests that the north and west of Scotland faced the most dramatic woodland decline in Scotland, the area is thought to be more sensitive to climate fluctuations, with less forest vegetation to begin with (Oosthoek, 2013). Carter *et al.* (2005) discuss that it was previously perceived that Loch nan Eala seemed to reflect a wider regional decline in woodland from about 2600 Cal BP, however, it appears that within this core, the first notable decline of woodland is within LNE2/A at 3492 Cal BP. Carter *et al*., (2005) notes Arisaig does see patterns of regeneration appearing patchy and irregular, but this is much later during the Iron Age.

The dip in tree pollen may be caused by environmental factors, however, it has been noted at Polnish that there were possible signs of *Quercus* exploitation from around 3800 Cal BP (Clarke, 2000). We are seeing a slight dip in *Quercus* pollen in LNE1/B at 4001 Cal BP, LNE1/C at 3690 Cal BP and a decline in LNE2/A at approximately 3492 Cal BP after a peak of *Quercus* at 3566 Cal BP. We may indeed be seeing similar signs of exploitation at Loch nan Eala, as well as time given for regeneration before further exploitation. The management of the woodland would have been important for wood production and CFS evidence for *Sordaria-type (HdV 55-A)* and *Arnium-type (HdV 261/262)*, are noted at low levels within LNE2/A. Small spikes in *Artemisia* and *Rumex* are also present within LNE2/A, which are often associated with grazing animals. A major dip in pollen such as *Corylus-type* and a small dip in Poaceae*,* may indicate that browsing animals were eating the foliage, as *Corylus-type* and young tree shoots are favourable to browsing animals. This may cause a stunted growth season for many trees and shrubs, taking more time before regeneration and reestablishment of the area. Perhaps within LNE2/A there are the beginnings of signs for similar practices of landscape modification and a shift to a grazing environment, although the NPP levels may be related to dung created by grazing wild animals rather than domesticated animals. The trends being seen in this subzone may relate to sustained management of the woodlands as well as continuous low levels of occupation or use (Carter *et al*. 2005:27).

The increase of Cyperaceae and low levels of other herb pollen such as *Rumex*, *Artemisia* and Poaceae, may also suggest signs of increased grazing regimens and woodland management as sedge types thrive in open spaces with an open canopy and less competition for light. A notable dip in percentage of *Pteridium* (bracken) spores was also recorded at 3492 Cal BP, which may indicate clearances occurring at Loch nan Eala. *Pteridium* was often used as a resource within the past, particularly for animal bedding, cover mulch and even weed control for vegetable crops (Donnelly *et al*., 2006), although not for fodder as it is poisonous to animals (Stegelmeier *et al*., 2013), although low levels occurring may suggest that it was not being exploited at the site, or that it was being cleared to allow for grazing livestock.

Based on the pollen spectra identified within LNE2/A, the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type,* with high peaks in Cyperaceae which was likely dominant in the wetter areas closer to the loch edges. As discussed previously in LNE1/C, there are a range of archaeological sites being seen throughout the local and more regional area which may relate to human activity within this period. The kerb cairn ^{14}C dates (see Table 1) provide similar periods of activity as this subzone, indicating that Bronze Age peoples were continuing funerary practices near Loch nan Eala. Within this period, we are seeing signs of browsing and grazing regimes as well as possible woodland management. The more general regional decline in woodland is also seen within this subzone, appearing later than the noted Arisaig woodland decline in pollen records from Carter *et al*. (2005) (see 43, 44 and 45).

6.1.5 LNE2/B

3413 – 3342 Cal BP (Middle Bronze Age)

LNE2/B presents some interesting trends, following LNE2/A, a spike in Poaceae pollen is noted, perhaps suggesting beneficial conditions for growth with nutrient rich soils and an open canopy for sunlight. This peak in Poaceae is coupled with a spike in *Sphagnum* moss, which has a consistently low relative abundance previously, suggesting a move to more open spaces, perhaps for grazing. Signs of grazing activities are also seen in the frequent occurrence of CFS *Sordaria*-type (HdV 55-A) and *Arnium*-type (HdV 261/262) throughout the subzone (see Figure 40). As both fungal taxa are coprophilous, this may be a continued use of the surrounding environment as a place for grazing animals. The increased percentage of *Sordaria*-type and *Arnium*-type could be indicative of pastoral activity related to the humans within the area rather than wild grazing animals. *Plantago lanceolata* is present in low relative abundances through this subzone (see Figure 39). The occurrence of this pollen has been used as an indicator of human activities in many areas of the west coast of Scotland and the Western Isles (Fossitt, 1996, Brayshay and Edwards, 1996, Bennett and Hill, 1998, Smith, 1970, O'Connell, 1987, Davis and Tipping, 2004). While the relative abundance is very low here, it could still indicate potential human impact on the landscape around Loch nan Eala.

A spike in *Typha angustifolia* and *Potamogeton* throughout the subzone suggests a wetland environment with an influx of freshwater into the Loch. An increase in water levels and freshwater may be related to the isolation and final exclusion from marine tidal influxes at 3440 ± 50 BP (Shennan *et al*., 1994), a similar date to radiocarbon dates 3448 Cal BP. According to Diatom evidence taken from a core located near to LNE97/1, Shennan *et al.* (1994) suggest supporting evidence that 3440 ± 50 BP marks the rise of an increasingly freshwater assemblage, including the halophobic taxa *Tabellaria flocculosa*, and *Eunotia arcus*, and post-dating *Fragilaria brevistriata*, *F. pinnata* and *Cocconeis placentula* (see Appendix Figure 47).

At a period more regional changes are occurring, Anderson (1997,1998) suggests a major wet shift occurred in the Northwest of Scotland between 3340-3060 Cal BP, with the earlier date coinciding with LNE2/B. A dip in solar activity is also noted at around 3413 Cal BP by Steinhilber *et al.* (2009) which may have led to a decline in arboreal pollen. A decrease in arboreal pollen continues until the end of the core, with a gradual dip of *Betula* and a steady but low amount of *Alnus* being present from 3412 – 3342 Cal BP. *Alnus* being a taxon with a high tolerance to wet conditions (Lowe and Walker, 1997), would likely survive increased precipitation and a higher water table, yet *Betula* may be more susceptible to the change. The decrease in *Betula* may also be due to anthropogenic factors, deforestation and land management may have led to the drop in arboreal pollen, we can see the use of birch logs in Crannog 1 at Loch nan Eala, so *Betula* would have been a useful resource to Bronze Age peoples. It is suggested that the species was affected by not only regional climate changes but also local factors which may influence its survival rate (Whittington *et al.*, 1991). Perhaps a varying combination of local, regional, and human impact sparked a change in vegetation, similar to that seen more broadly in Scotland at the end of the Bronze Age (Dubois and Ferguson, 1985, Gear and Huntley, 1991).

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type,* with some *Betula* woodland, a slight decline in Cyperaceae growing in the landscape. LNE2/B sees final exclusion from marine tidal influxes as well as a major regional shift wetter climatic conditions at 3340-3060 Cal BP (Anderson, 1998). The major dip in *Betula* at 3342 Cal BP may indicate signs of deforestation, also peaks in Poaceae around 3413 Cal BP, can be seen as evidence of more open areas which would be favourable for grazing animals. As discussed previously in LNE1/C and LNE2/A, there are a range of archaeological sites seen throughout the local and more regional area which may relate to human activity within this period. The kerb cairn located north-west of Loch nan Eala provided ^{14}C dates from *Quercus* charcoal, dating to 3370 – 3080 Cal BP, suggesting engagement with the cairn was occurring within this time period (Carter *et al.*, 2005).

6.1.6 LNE2/C

3289 – 3236 Cal BP (Middle Bronze Age)

As mentioned in LNE2/B, a shift to a wetter climate occurs around this time in the Bronze Age in Northwest Scotland (Anderson, 1998). More rainfall causes more grass growth and favourable grazing activities (Evans, 1960). A prominent increase in *Galium* between 3289 to 3236 Cal BP occurs, perhaps suggesting a damper and more open environment as other herb pollen such as Cyperaceae and Poaceae are also present. *Galium*, a damp loving versatile weed, has been used throughout history as a source of food, medicine and animal feed (Defelice, 2002). As the plant is edible by humans and animals, as well as a good source of bedding when dried, it could very well have been used by the Bronze Age peoples in the Arisaig area. Although there are multiple uses for *Galium* to humans, there is no documented evidence for the inclusion of charred *Galium* seeds in the archaeobotanical reports in the Arisaig area, this is in part due to the lack of accessibility to available archaeobotanical reports as the main focus of these reports was charcoal and cereal

species. The sudden decline of the species at 3236 Cal BP (see Figure 42) may indicate a move to a less favourable environment with less open canopy space, rather than human agency.
As there is no strong evidence for *Sphagnum* moss, which creates 'rougher grazing' ground (Whittle, 1981), the area surrounding Loch nan Eala may have been a good grazing area during this time for sheep and cattle, spikes and dips in herb pollen as well as shrub and tree pollen may have been the direct result of animals eating saplings and grasses, although this may be difficult to prove. Evidence of the NPPs *Sordaria-type HdV 55-A* and *Arnium-type HdV 261/262* fungi are present in consistent low percentages throughout (see Figure 40), may not indicate any anthropogenic activity and may simply suggest evidence of decomposition (van Geel, 1978, van Geel *et al*., 1983b, van Geel *et al.,* 2003, Baker *et al.,* 2013).
A sharp rise in *Equisetum* spores occurs towards the end of the subzone, *Equisetum* has been thought to be highly toxic to livestock with varying rates of toxins depending on the type and growing conditions of the plant (Rapp, 1954, Müller *et al*., 2020), if past peoples knew the properties of this toxic plant, areas of land may have been lost to unfavourable conditions for livestock.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type,* with high peaks in Cyperaceae which was likely dominant in the wetter areas closer to the loch edges, a spike in *Galium* pollen and *Equisetum* spores also represents a fairly herb and shrub dominant environment with patches of *Equisetum* and *Sphagnum* in the areas. The spike in wetter favouring species such as *Galium* and Cyperaceae may suggest a move to a fen environment. As discussed previously in LNE1/C and LNE2/A, there is a range of archaeological sites present throughout the local and more regional area which may relate to human activity within this period, see Tables 3 and 4.

6.1.7 LNE2/D

3183 – 3131 Cal BP (Middle – Late Bronze Age)

High percentages of *Equisetum* pollen seen in LNE 2/C continue throughout most of LNE2/D, perhaps areas of land closest to the loch were no longer used for grazing due to the toxicity of *Equisetum* (see Figure 42). A decrease in arboreal pollen may reflect small clearance activities to allow for a wider space in which animals could graze safely. The rise of *Corylus-type* woodland in LNE2/D may also be the result of a more open canopy with more clearings and better growing conditions. There is, however, the presence of NPP *Sordaria-type (HdV 55-A)* seen throughout the subzone (see Figure 40), as well as low but persistent percentages of *Rumex* and *Plantago lanceolata,* suggesting that grazing animals were likely present at this time. NPP HdV 18b fungi are present at consistently low percentages with a peak at 3183 – 3131 Cal BP (see Figure 40), suggesting *Eriophorum* is present, and the likelihood of a boggier environment, although herb species are on the general decline within this subzone.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type,* with some peaks of *Alnus.* Cyperaceae is also present but declining and was likely dominant in the wetter areas closer to the loch edges. Patches of *Equisetum* would have been present but declining throughout subzone. As discussed previously in LNE1/C and LNE2/A, there are a range of archaeological sites being seen throughout the local and more regional area which may relate to human activity within this period.

6.1.8 LNE3

3078 – 2972 Cal BP (Late Bronze Age)

LNE3 is characterised by the lowest levels of arboreal pollen seen throughout the core (see Figures 39, 40 and 42). LNE3 continues at low levels of arboreal pollen with *Corylus-type* as the dominant taxon, *Corylus-type* has a small dip around 2972 Cal BP where *Alnus* peaks but it is still at very high percentages, suggesting some competition in the environment. When comparing to sites such as Lochan Doilead and Allt Dail an Dubh-asaidh, the tree pollen percentage is much higher at approximately 70 – 85 % TLP (Carter *et al*., 2005), drastically different to the shrub dominant record seen in LNE3. The land may have been exploited by human activity and within LNE2/D, we are seeing a period of low rejuvenation of trees, perhaps as the land had been modified to fit particular purposes such as land for grazing and we are seeing the results of peak impact.

A large spike in *Equisetum* is seen in LNE3, which is countered with a large dip in *Corylus-type*, it may suggest a move to wetter conditions as very high levels of HdV 18b fungi from *Eriophorum* was also noted. Low but continuous percentages of *Rumex* and *Artemisia* were noted in LNE3, which may be related to grazing activities, matching the interpretation for an impacted environment.

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as a *Corylus-type* dominated open wooded area, with some peaks of *Alnus* growth, and Cyperaceae, likely *Eriophorum*, in the wetter areas. As discussed previously in LNE1/C and LNE2/A, comparative archaeological sites suggest a range of anthropogenic activities taking place in the area, although no specific ^{14}C dates can be provided to match this zone, general Bronze Age dates have been given (see Tables 3 and 4), meaning that sites may be linked to this period.

6.1.9 LNE4

2919 – 2810 Cal BP (Late Bronze Age)

The top of the core, dating to 2810 Cal BP, would coincide with the end of the Bronze Age and a generally accepted change in climate to wetter conditions with a cooling phase in northwest Scotland (Dubois & Ferguson 1985, Gear & Huntley, 1991, Charman *et al*., 2006; Tipping *et al*., 2008a; Wang *et al*., 2011). LNE4 may also coincide with the 2.8 – 2.6 ka event, or the transition between the Sub-Boreal and the Sub-Atlantic, in which there was a sudden period of cold (Bond *et* al, 2001, Wang *et al*., 2012) (see Figure 7). During the 2.8-2.6 ka event, higher precipitation is recorded and ocean proxies suggest clear changes in the North Atlantic with a drop of sea surface water temperature by 1-1.5°C (Charman, 2010). LNE4 may not have yet experienced the cold event at 2810 Cal BP. It is interesting when comparing LNE4 tree percentage to other surrounding sites such as Lochan Doilead, Polnish and Allt Dail an Dubh-asaidh, as the sudden drop in temperature does appear to impact arboreal pollen at around 2800 Cal BP, Lochan Doilead, Polnish and Allt Dail an Dubh-asaidh show a decrease in arboreal pollen by approximately 15 – 30 % at this time (see Figure 8, Carter *et al*., 2005). If we apply this pattern to LNE4, that arboreal pollen may have also been impacted at Loch nan Eala from the 2800 Cal BP cold event, which is slightly after the last core sample, theoretically there would be a decrease in pollen. Interestingly, the spike in *Betula*, *Quercus* and *Alnus* at 2810 Cal BP indicates that trees are surviving and on the rise at the time of the last ^{14}C sample provided within LNE97/1. Figure 8 demonstrates that there is already a decrease in arboreal pollen at Lochan Doilead, Polnish and Allt Dail an Dubh-asaidh, even before the 2800 Cal BP cold event, whereas at Loch nan Eala, there are dips and peaks, but a general increase towards 2810 Cal BP (see Figure 42). The peaks and dips being seen within *Betula* pollen in particular may be the result of forest management with stages of deforestation and periods of regrowth. A large spike between 2919 – 2868 Cal BP is seen in *Betula* pollen indicating that arboreal pollen is successfully regenerating after the sudden dips, especially at 2919 Cal BP, and there is a continuous pattern of peaks and dips, likely the result of woodland clearances and regrowth. The decline in woodland within LNE4 could also be related to increased grazing on the outskirts of the Loch, although this is difficult to distinguish directly in the pollen record. As Carter *et al*. (2005) suggest, factors in woodland decline that are usually related to humans, are implicated by the rise in ruderal herb pollen. The small peak in *Rumex* at the end of LNE3 and start of LNE4, may also be an indicator for increased grazing, or human activity during this time. The presence of some *Rumex* species can occur in wet meadows, pastures and grasslands (Behre, 1981, Doyen and Etienne, 2017). However, assigning significance of human activity to *Rumex* can often be difficult, as the absence of species-specific identification may cause misinterpretation due to the wide ecological range each species inhabits (see Behre, 1981, Tamis *et al*., 2004, Doyen and Etienne, 2017). *Sphagnum* moss shows a small spike at 155 cm, perhaps suggesting a move to more acidic soils (see Figure 40).

Cyperaceae is on the rise throughout LNE4, as well as more species of shrub and herb pollen being seen for the first time within the core, especially at 2810 Cal BP (see Figure 42), implying a more open area with less competition from canopy cover, as most tree pollen remains at very low levels, with exception of *Betula*, which shows prominent peaks and dips in the zone.

Within LNE4 *HdV-18b* was present in high amounts (see Figure 40), making a strong suggestion for the presence of *Eriophorum. Eriophorum*, indicated by the NPP *HdV-18b*, thrives in wetter conditions and is reliant on high quantities of light for survival (Grime *et al*., 1996). With an open canopy and less competition for light, *Eriophorum* would thrive. This may relate to the reduction in *Corylus-type* and increase in herb pollens such as Cyperaceae / *Eriophorum*. As mentioned previously, the precipitation levels occurring in the Late Bronze Age in Northwest Scotland are higher than in earlier periods (Anderson, 1998), and the fluctuations will be area specific, the rise of *Eriophorum* may be suggesting a boggier environment in LNE4. At 2810 Cal BP the highest percentage of *Sordaria-type (HdV 55-A)* is seen in this zone (see Figures 40 and 42), with other indicators for disturbance such as *Rumex*. It is very likely we are seeing evidence for browsing and grazing animals, especially as human activity in the late Bronze Age is supported by archaeological sites in the Arisaig area, as shown in Tables 3 and 4 (also see Carter *et al*. 2005).

Based on the pollen spectra identified within this subzone the interpretation of the environment of deposition can be summarised as an open wooded area of *Corylus-type*, with peaks of *Betula*, and gradual dominance of Cyperaceae, *Eriophorum* at 2810 Cal BP. A big change is seen in this zone, with clear signs of the canopy opening up and herbs overtaking shrubs, likely relating to human activity. A rise in spores suggests *Equisetum* was present also. Comparative archaeological data at Home Farm in Portree, Skye, shows a ring ditch dating to the Late Bronze Age roundhouse, containing well preserved cereal grains consisting mainly of barley with occasional oat (Suddaby, 2007f). Barley chaff fragments were found in the fill of the ring ditch, suggesting that the grain was being dried as whole ears, which is a rare find from Scotland (Suddaby, 2007, ScARF, 2022). It is noted by Tipping (1994) that the Bronze Age shows an intensification in agriculture, despite evidence of worsening climatic conditions. Although there is no evidence for cereal pollen within the core, it is evident from comparative sites in the area, that cereal plants such as Barley and Oats were being exploited as a resource. Events of deforestation seen within this zone may relate to resource gathering as well as management of the landscape for agricultural purposes such as crop sowing and animal grazing, even if the pollen record may not see evidence for cereal grains in the catchment area.

6.2.2 Discussion in trends

Varying factors should be acknowledged when discussing agriculture within Bronze Age Scotland, issues in soil fertility, attitudes that past peoples had towards places related to plant cultivation, as well as survivability and visibility of fossils and can mean that a lack of presence in the palynological and archaeobotanical record, does not necessarily mean that agriculture did not take place there. There is indeed a greater need for further exploration of agriculture in the pollen and archaeological records within the Bronze Age of the Argyll area (Tipping, 2018). The catchment area for Loch nan Eala consists of a fairly sizeable area which easily includes a 3km² area, but likely to be greater due to the location of LNE97/1 core lying within the Loch nan Eala basin. To understand and interpret the pollen record correctly, we must be mindful that the data represents the area as a whole, rather than just the site of Loch nan Eala itself.

Modes of transport of pollen also provide a factor for consideration when interpreting pollen data, flowing streams can introduce pollen from a wider catchment (Pennington *et al.*, 1972, Tauber, 1977). Any streams flowing downhill in the basin, running into a loch can do this, however Loch nan Eala has a relatively small catchment area with similar vegetation (see Williams, 1977, Shennan, 1994, 1995, Clarke, 2000, Carter et al., 2005), so it is likely that this is not a major issue in this study. Other transportation issues can also obscure trends in the data, some pollen, such as *Pinus*, can travel over large distances, providing a more regional signal compared to pollen grains deposited close to a given site (Sofiev et al., 2013, 2015). The small percentages of *Pinus* that are seen throughout Zones LNE1-4 are most likely to have been delivered from some distance and not from the catchment itself, as pine forests are noted to be notoriously overrepresented in pollen diagrams (Bennett, 1984, Fossit ,1994). It is, therefore, unusual that Loch nan Eala has such a small percentage of *Pinus* pollen. *Pinus* was also diminishing in rates in Scotland in the 'pine-decline' event, which occurred between ca. 4200 and 3300 Cal BP (Birks, 1975, Bennett, 1984, Gear and Huntley, 1991, Tipping et al., 2008a). This may be seen in a small decline at 3749 Cal BP in the age-depth model (see Figure 42), although the quantity of *Pinus* seen at Loch nan Eala is very low in percentages. Due to *Pinus* pollen transportation, this may leave some question on external pollinators distant to the site. Fluctuations in pollen may be related to water levels of the loch and competition for growing space. There have also been incidences where although presence of pine pollen was low, Pine stumps were found from late Boreal chronozone in Setesdalsheiene, southwest Norway, (Selsing, 1999). Selsing (1999) also discusses the presence of pine subfossils but lack of pollen may indicate dominant strong winds that cause pollen to settle elsewhere. A study of tool-marked prehistoric *Pinus* stumps from Kilbraur, in Sutherland, also demonstrated the presence of pine macro evidence that can be hidden within the peat (Timpany, 2010), something which may occur at Loch nan Eala, although further investigation is needed. The site also highlights the impact that Bronze Age peoples had on their landscape. The act of turfing peat in the Bronze Age caused axe marks to be created in the Neolithic buried pine stumps (Timpany, 2010), peat turf may have been used as a resource for burning, so it is important to not solely rely on the idea of wood for burning. Vegetation changes may often relate to climate change, however, the expansion of settlement and agriculture during the Holocene caused a ripple effect on the development of the landscape (Edwards and Whittington, 2003, Edwards et al., 2019). The peaks and dips seen especially in *Betula* throughout LNE2/A-D, LNE3 and LNE4 are interesting and may represent coppicing activity (see Figure 39). The sudden peaks and drops *Betula* in these zones may indicate patterns in pollination which in between coppicing, with peaks relating to periods of growth and dips indicating the inability of the tree to produce pollen. The undulating pattern may also relate to deforestation activities, although it is can be very difficult to detect sustainable timber-management practices (Waller *et al*., 2012), these woodland management practices would have existed on a landscape scale in Arisaig. These temporary reductions in relative proportions displayed in the arboreal pollen curves, is likely indicating human activities such as coppicing or deforestation from the increase of pollen successions during the re-establishment of the woodlands (see Faegri et al., 1989, Edwards and Whittington, 2000, Innes et al., 2010, Laine *et al.*, 2010, Robinson, 2014).

When comparing trends seen in arboreal pollen within core LNE97/1 to the surrounding region (see Figure 8), there appears to be some noticeable similarities. Comparisons between pollen data from Allt Dail an Dubh-asaidh (Figure 8) and Loch nan Eala, show a similar trend in *Alnus* pollen, when overlapping the similar time period to this study, *Alnus* is particularly prominent in the Late Neolithic, dominating most of the TLP percentage. Although Loch nan Eala does not show quite a prominent Alnus environment in the Late Neolithic, *Alnus* shows a similar decline, especially at the start of LNE2/A, likely reflecting the more regional arboreal decline, perhaps from the sudden cold climates seen in Figure 7 graph from Langdon *et al.* (2004), or perhaps a more local move to a drier environment. *Quercus* remains at fairly low percentages throughout the region, with some slight sudden spikes at Allt Dail an Dubh-asaidh in the Late Neolithic, at roughly 400cm depth (see Figure 43), (although this could be an anomaly of data due to the sudden dramatic spike), the only regional data that suggests *Quercus* is thriving is at Mointeach Mhor (see Figure 8), in the periods between 3005 ± 45 – 2565 ± 45 BP, or roughly Early Iron Age to Middle Iron Age. Loch nan Eala may start to have seen a similar growth pattern with the slight rise in *Quercus* pollen in LNE4, but due to the core ending at 155cm, further investigation was not possible. The pollen in Rumach lochdar (see Figure 45), is difficult to use due to the only date provided was 10755 ± 90 BP at a depth of 305cm, but it does appear that *Quercus* maintains a low pollen percentage throughout the core. However, at Polnish (see Figure 8), there were possible signs of Quercus exploitation in the pollen record from around 3800 Cal BP (Clarke, 2000). At Allt Dail an Dubh-asaidh, there was a similar pattern in the pollen record for *Corylus*, indicating fluctuations but maintaining a moderately high percentage, similar to Loch nan Eala. In the regional pollen data of the Arisaig area, *Pinus* appears at low levels in the Late Neolithic to Early Iron Age period, at Allt Dail an Dubh-asaidh, there is a sudden decline in *Pinus* from roughly 6070 ± 65 BP, which may be an example of the more wider scale Pine decline event. We may see a small pine decline event in LNE1/B, but the percentage of *Pinus* pollen is fairly low in comparison to other areas of Scotland and is much less noticeable in the pollen record.

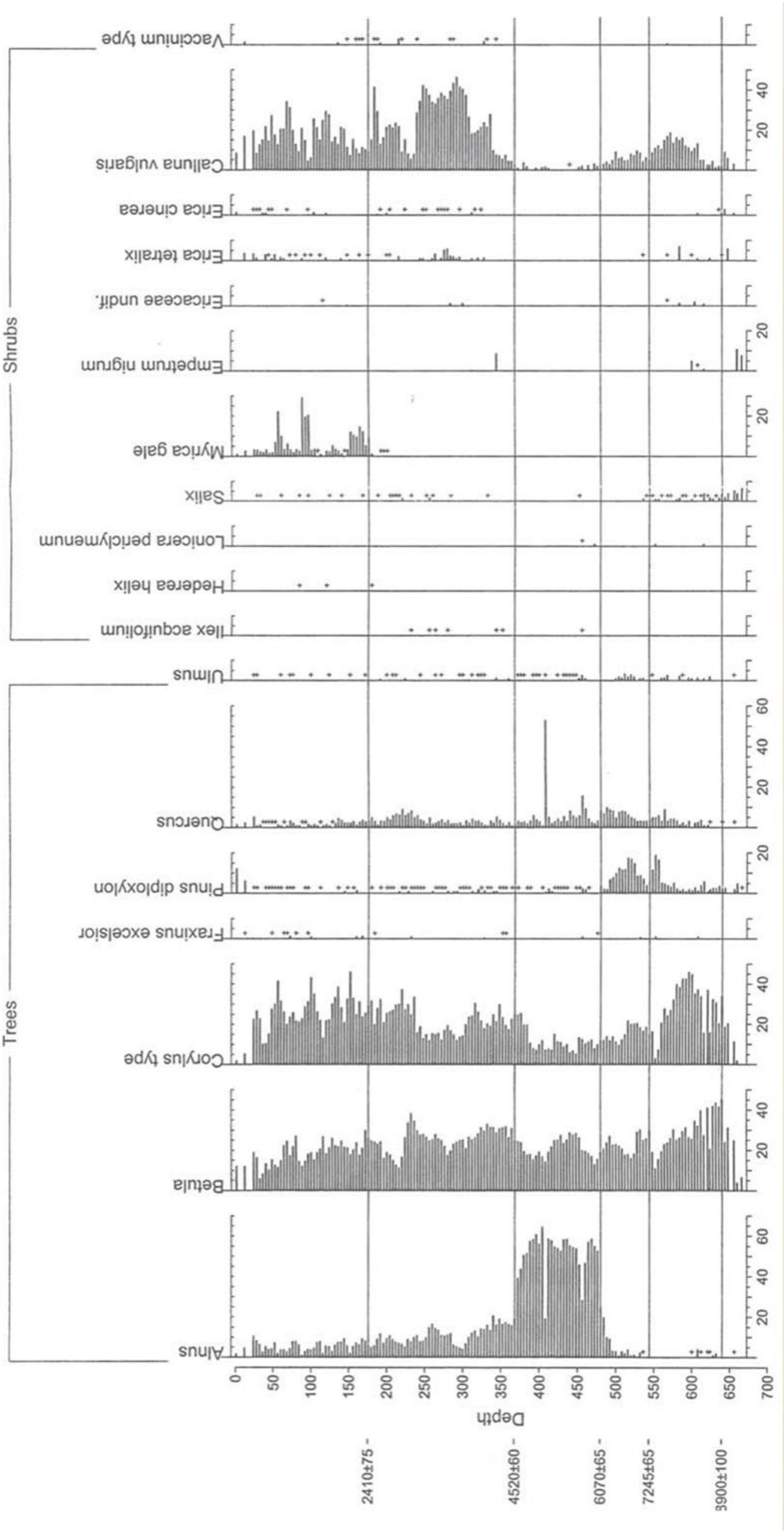


Figure 43 Allt Dail an Dubh-asaidh percentage pollen diagrams for trees and shrubs, from Carter et al. (2005)

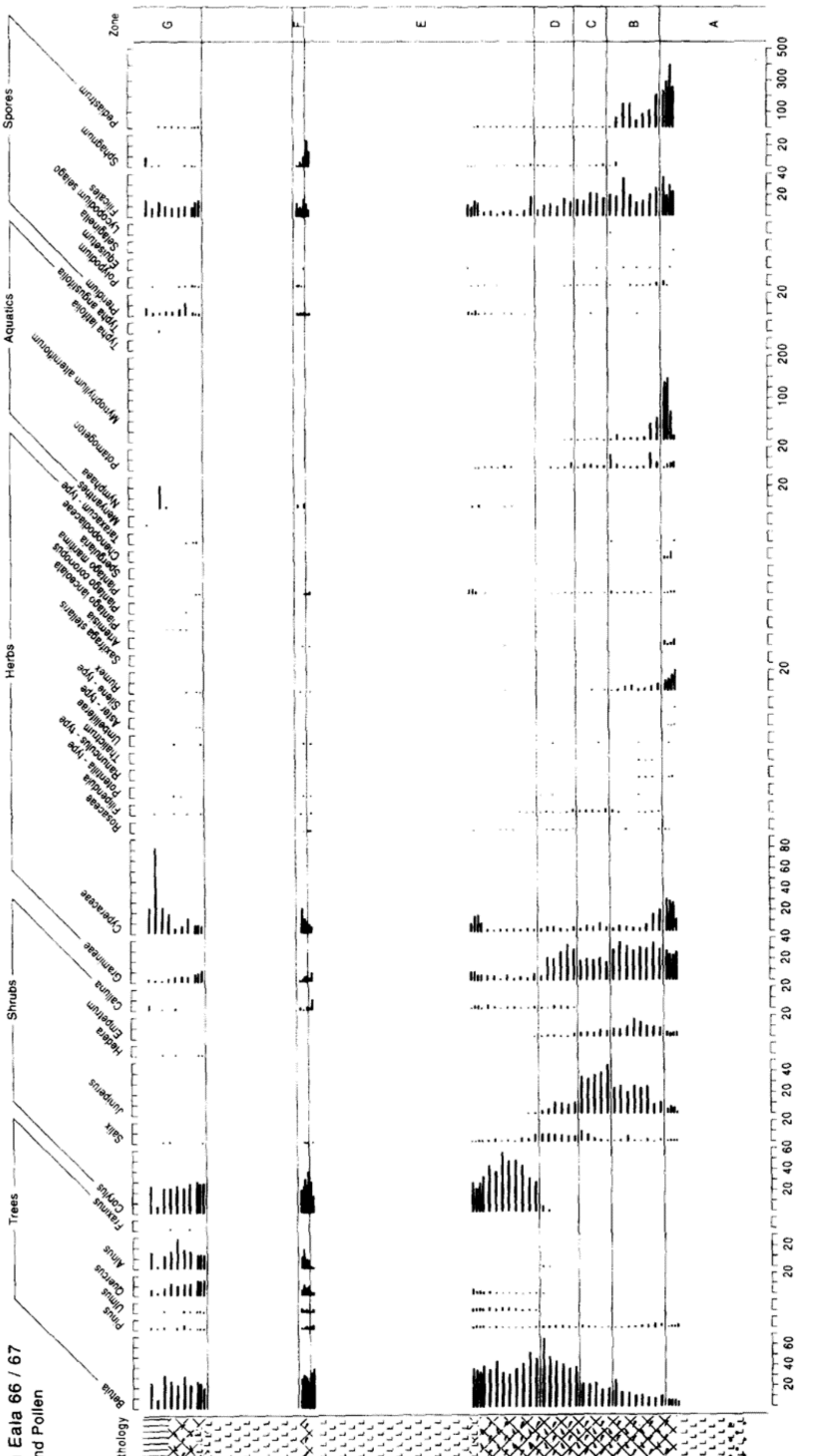

Loch Nan Eala 66 / 67
% Total Land Pollen
Trees
Shrubs
Herbs
Aquatics
Spores
Zone
Lithology
Depth (cm)
m. O.D
Betula
Pinus
Ulmus
Quercus
Alnus
Fraxinus
Corylus
Salix
Juniperus
Hedera
Empetrum
Calluna
Gramineae
Cyperaceae
Potamogeton
Myriophyllum alterniflorum
Filicales
Sphagnum
Pediastrum
4010 ±50
6630 ±50
8310 ±45
10500 ±90
A
B
C
D
E
F
G

Figure 44 Pollen diagram from Loch nan Eala, displaying the percentages of pollen (Shennan et al., 1995)

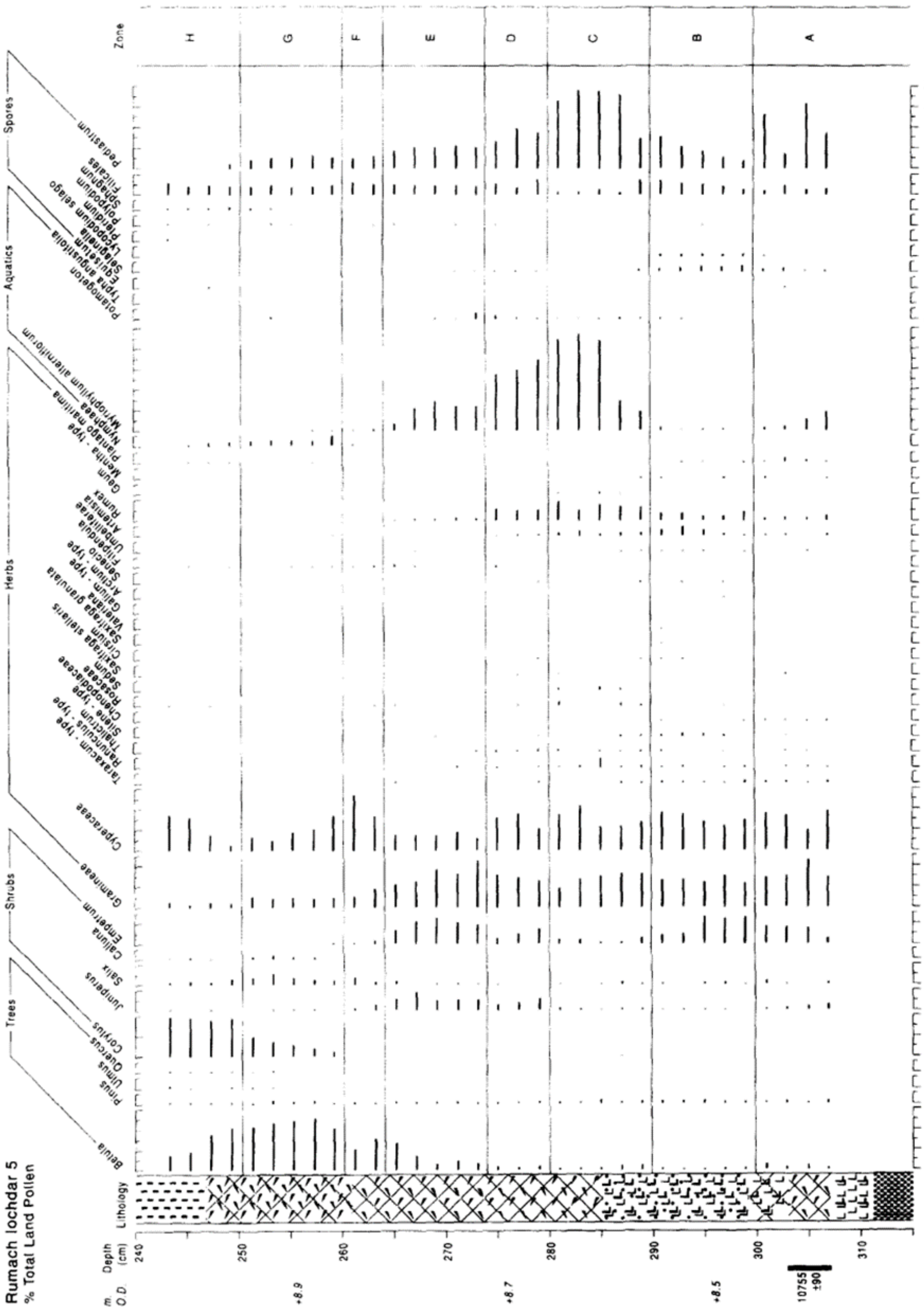


Figure 45 Pollen diagram from Rumach lochdar, displaying the percentages of pollen (Shennan et al., 1995)

Although there is an absence of cereal pollen within the pollen record at Loch nan Eala, how humans made use of the woodland may be present in the form of coppicing, use in building materials or for gathering woodland biproducts such as hazelnuts for consumption. The presence of coppicing may be seen in cycles of pollen decrease and then increase, as pollen production will be affected by coppicing the trees. LNE1/A demonstrates a pattern of increase/decrease cycles of *Corylus* pollen, the individual sample depths are approximately 67 years per sample in the lower section of the core (see Figure 42), which would give the coppiced trees enough time to regenerate their maturity for pollen for dispersal. There is a steady pattern of pollen cycling throughout Zone 2 with *Betula*, however, it is unclear as to whether humans would be copping *Betula*, and may just be the result of woodland management or clearances of that species in particular. Both *Quercus* and *Betula* pollen begins to decrease from the beginning of Zone 2, around the mid Iron Age, which may be an indicator of their favoured use in building materials in the Arisaig area due to their strength and durability, it has been mentioned by Mapleton (1870) that Quercus and *Betula* were found at Crannog 1, as part of the structure. We may also be seeing an increase of *Corylus* this within LNE2/B and Zone 3 for both coppicing and increasing food sources, a dramatic increase in the presence of *Corylus* occurs but there are some dips especially within zone 3, which suggests that humans were managing *Corylus* as a way to provide building materials and for hazelnut production. Hazelnuts are a very easy and favourable food for humans to gather, and it could indicate a food management strategy in the Middle Bronze age to Early Iron age of Arisaig (see Huntley, 1993), as Hazelnuts become available in the autumn, they can be stored easily for a reliable winter food and they provide humans with a good source of protein and carbohydrates (Irving, 2009). The surrounding sites do not have any recorded evidence of Hazelnut fragments that were found belonging to a similar period, Carter et al. (2005) mention the presence of burnt hazelnut fragments found in a pit located in a shielding hut likely dating to roughly 840 Cal BP, similarly, Crannog 1 at Loch nan Eala contained fragments of burnt hazelnut shells (Mapleton, 1870), but these were only mentioned in the records of the excavation from the 19th century and consequently lost. Although we have no direct evidence to say the people in Arisaig were eating hazelnut shells, it is most likely they were due to the ease of availability and access to them, unlike acorns, hazelnuts do not need to be treated before eating, and can be eaten raw or cooked (Irving, 2009).

The lack of dwarf shrubs such as *Calluna* (Heather) and *Erica*-types (Bell Heather) found in these pollen spectra is rather difficult to explain as present day vegetation at Loch nan Eala consists of *Sphagnum* moss with abundant *Calluna vulgaris*, *Eriophorum* and grasses present in the drier areas. The surrounding sites such as Allt Dail an Dubh-asaidh (see Figure 43), show high quantities of

Calluna pollen (see Carter et al., 2005). Sites surrounding Loch nan Eala such Mointeach Mhór in Arisaig (see Figure 8), show the first peak from 2585 ± 45 Cal BP (Shennan et al., 1994, Shennan et al., 1995) whereas Rumach also presents fairly low levels of *Calluna* and *Erica*-type at shallower depths in the stratigraphy of the core similar to Loch nan Eala, unfortunately 10755 ± 90 Cal BP was the only date provided for Rumach, so a comparative date cannot be estimated. Plants such as *Calluna vulgaris* (common heather) produce large quantities of pollen (Faegri et al., 1989), suggesting it is unusual that they are not being seen in the pollen record. It can also be argued that a taxon such as *Calluna vulgaris*, which is a zoophilous plant, may only occur in the palynological data if the study area picks up soils beneath the plant itself (Faegri et al., 1989). *Calluna vulgaris* may likely be underrepresented in the pollen record (Evans and Moore, 1985). It has been noted that only at about AD 600 do heath pollen types start to increase, most notably with the start of the increase in *Calluna vulgaris* pollen.

The absence of a strong *Sphagnum* spore count can also be seen as unusual as it is a common species to grow in areas similar to Arisaig and is often discounted within counts and interpretations of palynological data. It appears that Sphagnum moss appears at very low to sparse levels throughout the Morar area in studies at Rumach, Mointeach Mhor, Glenancross and Kentra Moss (Shennan et al., 1995), the exception of Loch nan Eala upper basin, where core LNE66/67 shows some higher levels of Sphagnum at 10500±90 to 6630±50 Cal BP, which is much older than the present study, also at Allt Dail an Dubh-asaidh which shows high levels of *Sphagnum* in at approximately 7245±65 to 8900±100 Cal BP (Shennan et al. 1994, 1995, Carter et al. 2005). The older dates at Loch nan Eala and Allt Dail an Dubh-asaidh, show how *Sphagnum* was present in the environment, but this decreases dramatically until very little *Sphagnum* is seen in the record during the Neolithic to Late Bronze Age at Loch nan Eala.

The core provided no evidence of cereal pollen in the data. A fine resolution approach aimed to investigate whether any cereal pollen could be identified within periods of human activity in the surrounding landscape through archaeological sites dating to similar periods in time. In general, evidence from the Scottish Early Bronze Age sites show an intensification of agriculture, despite evidence of worsening climatic conditions, as the period advances (Tipping 1994). Although an intensification of agriculture was occurring elsewhere, land use in the highlands of Scotland is generally thought to have been managed on a smaller more intensive scale (Davies and Tipping, 2003). Arisaig shows a similar distinctive pattern, low intensity land use appears common in the peripheral areas and extensive sites of land use appear to be repeatedly reused (Carter *et al.*, 2005:27), see Tables 1 to 4. Agricultural practices may thus have operated at too small a scale to be detected within the pollen data as pollen related to farming tends to be localized to a key area

(Tipping, 1994, Willis and Bennett, 1994, Sugita *et al*., 1997, Davies and Tipping, 2004, Halstead, 2000). Furthering this idea, the presence of macrofossil evidence for Bronze Age charred cereal grains at sites such as Lairg, where six-rowed barley was found within the archaeological record and relatively scant evidence for cereals in the pollen record, the team was not able to correlate the evidence for tillage with local cereal production (Tipping, 2015: 109). The lack of a presence within the data from Loch nan Eala may not be representative of human agricultural activities in the local area as the use of palaeoecological techniques to determine human inference can be challenging (Davies, 2007, Tipping *et al*., 2009, Innes *et al*., 2010, Bishop *et al*., 2015). The absence of strong anthropogenic indicators, in particular the lack of cereal pollen, can be largely due to issues in transport, survival and pollination, as well as the suitability of the immediate area for cereal cultivation, rather than a sign of no human activity (Edwards *et al.*, 2005). Autogenous, or self-pollinating plants, such as *Triticum* (wheat) are self-pollinating and produce few pollen grains. Cereal grains tend to fall close to the site of pollination and they are generally underrepresented in the pollen record (Faegri *et al*., 1989, Edwards *et* al., 2005, Tipping, 2015). Although agricultural activity is generally the immediate signifier to identify human activity within the area, few sites provide evidence for cultivation (Davies and Tipping, 2003: 234). Behre (1981) argues that palynological evidence for human activity consists, almost exclusively, of very low or sporadic pollen frequencies of 'anthropogenic indicator' herbs associated with pastoral disturbances, similar to what has been discussed above within the different phases. Similarly, sites such as the Bronze Age roundhouse at Home Farm, Portree, had virtually no cereal remains, yet, the ring ditch of the Late Bronze Age roundhouse at the same site had well preserved remains consisting mainly of barley with occasional oats, the interpretation of this may be due to differences in domestic function of each site (Suddaby, 2007). Other elements regarding agricultural activities that are often overlooked is the evidence of soil improvement and soil cultivation, a few sites have identified Bronze Age ard / plough marks in Scotland as well as evidence for manuring through middening (Mercer, 1996, McCullagh, 2011, Cavers *et al*., 2016). At Skaill in Caithness, ard marks predate an Early Bronze Age burnt mound (Cavers *et al*., 2016) whereas at Cnoc Stanger near Reay, Caithness, machair soils were cultivated, with traces of ard marks as well as evidence of manuring with domestic midden material including cooked animal bone, seaweed and shells (Mercer, 1996, Cavers *et al*., 2016). At Lairg in Sutherland, there was also evidence of the constant improvement of soil fertility, a practice in the Bronze Age that deserves far greater attention (McCullagh, 1989, 2000, 2011).

Changes in vegetation may also be the result of loch level fluctuations, as suggested in the assessment of the different zones in the above chapters. Hydrological changes can dramatically change an environment depending on plant preferences, for example, damp loving species such as

Alnus tend to thrive in these periods of high water levels, this can create repercussions in species survival. The changes in the loch salinity can also affect plant species growth, due to the amount of salt content each species can handle. Increases in salinity to brackish water through increased loch levels, or sea level breaches, as possibly seen in LNE1/A, can change an environment over time through natural processes rather than human or animal agency.

The preservation of the pollen within the core must also be addressed, the general pollen preservation was recorded as often broken, corroded and degraded, with particular emphasis on poor preservation at the shallower depths (see Table 3 in appendix). The preservation of the core may relate to the limited availability of a core taken in 1997, as due to COVID19, no fieldwork was permitted. Although little damage was noted in preparation of the core for lab work, perhaps storage has caused some degradation to the pollen. It is difficult to hypostasise as it may be the preservation of the pollen located at that particular location of Loch nan Eala, Shennan *et al.* (1994) did not particularly raise many issues with pollen interrogation. It would be interesting for future projects at Loch nan Eala to compare the preservation of the pollen.

The anthropogenic indicators seen in the pollen data as discussed above suggest that there is evidence of human agency, however, it is difficult to link these to the Crannogs found at Loch nan Eala. Crannog 1 and Crannog 2 found at Loch nan Eala (see 3, 9), produced no datable evidence within the excavations in the 19th century and surveys in the 20th century, making interpretations of the timing of their use difficult. Crannogs in a more regional context have been dated from approximately the Bronze Age to the Post Medieval period in Scotland, with more recent investigations suggesting a prominence in construction of crannogs dating to the Neolithic especially within Scotland (Lenfert, 2013, Garrow and Strut, 2019). The crannogs found at Loch nan Eala were originally recorded dating to the Bronze Age (see HRC, 1986, report), with possible reuse through to the post-medieval period, as commonly seen in crannogs (Garrow and Strut, 2019). Crannogs have been found throughout Scotland (see Figure 12), although often associated artefacts or datable evidence is found in the waters surrounding it, giving archaeologists an approximate timeframe for when it was in use (see Garrow and Strut, 2019). At Loch nan Eala, no artefacts were found that could provide an estimated date of use in the 19th century excavations (see Mapleton, 1870).

The construction of the crannog itself could possibly be argued as a large enough event for it to be visible in the pollen record, as it was noted that the crannog consisted of oak and birch logs, measuring between 13 – 15 m in both length and width, with multiple layers of logs (Mapleton, 1870, Blundell, 1911). Although the crannog is fairly substantial in size, a deforestation indicator in the pollen record will depend on multiple probabilities which may lead to the construction phase not even being visible in the pollen record. Due to our limited cultural biases, we can only draw from a small pool of ideas in how much the construction of the crannog may have impacted the surrounding environment. If the construction of the site included large clearances of trees and vegetation, human agency in the surrounding landscape would be fairly noticeable in the pollen record, this also can be seen within areas being trampled and decrease in herbaceous pollen. There are signs of reduction in woodland, in particular *Betula* and *Quercus* (the materials that the crannog was constructed with) in various points throughout core LNE97/1, especially at 4392 Cal BP, 3342 Cal BP, 3289 Cal BP, 3183 Cal BP, 3024 Cal BP, 2919 Cal BP and 2868 Cal BP (see Figure 42). The dips in woodland may be reflecting this clearance event, although more evidence is needed to tie into the Crannog, in particular ^{14}C dates.

The purpose of crannogs in Scotland is still debated (Stratigos, 2021), which means an array of possibilities for cultural practices may have been possible. The examples ultimately aim to demonstrate the dangerous nature of assigning changes in the pollen record to the crannog due to the complexities of human activities surrounding it.

Occupation of the structure must also be taken into consideration, as the site itself may have been limited to a place to visit or nay have been a home for generations of families. The presence of calcified bone and hazel shells suggest eating took place there, however it is unlikely this was on a scale which could be seen in the pollen record. The sign of burning and eating at the crannog, implies that the site was used, but not enough evidence is seen to determine how frequently. The burnt flagstones mentioned by Mapleton (1870), shows there were at least three events of fire burning, although possibly each was used repetitively. The ramparts of the crannog suggest, as commonly found with crannogs, a more defensive use of the structure, although again, these interpretations are limited to architectural descriptions of Mapleton (1870) and Blundell (1911). Microcharcoal grains were seen in limited numbers within the pollen record (see Figure 40), however, this may not be related to the crannog, or may even be the remnants of the burnt material being washed away, although this is unlikely.

When looking at the past, we must consider the ideologies related to a structure; was the structure in use for limited times of the year? Were certain people limited to accessing the crannog? Or was this a domestic dwelling occupied for long periods of time? All of these questions may indeed affect the way in which we can see it in both the archaeological and environmental record, but again must be accompanied by a range of evidence. Ideas about the use of space in the past has been argued as an important factor that affects human agency (McFadyen, 2007, McFadyen and Barac, 2007, Thomas, 2013, Richards, 2020, Aldred, 2020). If habitual or ritual events were practiced, movement through the landscape may have shaped the way in which the crannog was accessed. Movement through the water by boat would completely limit any evidence of human agency in the pollen record. The connection of the main basin to the sea would have provided easy access, whereas if the crannog was constructed after the isolation of the main basin at 3745± 50 Cal BP (Shennan *et al*., 1994) then movement through the landscape would have been different. Within the NPP record, we can see fluctuations in NPP data, which may relate to animal dung fungi from FCS, which may have been the result of bringing animals to the loch outskirts to graze. Due to scales of impact, low human agency could easily be mistaken for a natural climatic or subtle environmental change in the area, high anthropogenic activities such as burning or large vegetational changes may give more of an indicator in the pollen record. However, it is clear in the pollen records from this study, as well as from Shennan *et al*. (1994), that there does not appear to be evidence of such a prominent event happening. Evidence seen in the pollen record at Loch nan Eala, does perhaps show some signs of tree clearance. Especially in LNE1 subzone D, LNE2 subzones A- C and LNE3 and LNE4, the dips in tree pollen may reflect some signs of human activity, but relating this to the crannog would be unwise. Small peaks of *Plantago lanceolata* are present in the pollen record, which appear to match decreases in tree populations and often suggest cultivated land. Although there is very little evidence to suggest this may be related to the crannog but more towards use of the local landscape.

Carter *et al.* (2005) discuss the idea of a small 'core' location of high intensity sites dating from the Bronze Age, with mention to Loch nan Eala as a potential 'key location' for settlement. The crannogs perhaps suggest a link to surrounding sites and the idea of change in society and movement in the landscape, but it is important to remember that the archaeological record itself is often biased to problems of visibility and preservation (Davies and Tipping, 2003), sites located in the uplands tend to be hidden by layers of blanket peat which have been extensive since 5700 Cal BP (Tipping, 2008). The fluid movement of humans through the landscape may cause invisibility or survivability of sites, especially with low intensity activities. However, the management of vegetation in the landscape may be evident from the pollen record of the area, especially within the Bronze Age. Carter *et al.* (2005: 27-30) support this theory with evidence from the pollen record documenting progressive woodland removal in the peripheral area of Allt Dail an Dubh-asaidh within the Late Neolithic through the present, however, the Arisaig region has no previously excavated evidence for human activity before the Middle Bronze Age, limiting interpretations (see Tables 1 to 4).

There have been discussions by Sugita *et al*. (1999) regarding the difficulty of identifying elements such as scale and intensity of land use in palynological identification, this was also evident in the pollen record from this core. Coupling data from archaeological sites and excavations, alongside palynological and faunal evidence, can help give a clearer understanding of occupation, but due to the lack of retained evidence from previous excavations at Loch nan Eala, this has greatly limited further investigations. Human activity on a more local scale within the landscape around Arisaig can be supported by the numerous archaeological sites dating to the Late Bronze Age, see Tables 3 and 4. Excavations in the road expansion scheme has allowed for more investigation of sites (see Carter *et al*., 2005). However, the low frequencies of ruderal taxa seen within the study are comparable with values recorded in many previous regional pollen sequences from northern Scotland (Davis and Tipping, 2004). Davies and Tipping (2004) discuss the issue of seeing little palynological evidence of anthropogenic activity, despite abundant archaeological evidence to the contrary, as in the Western Isles or at Lairg (Fossitt, 1996, McCullagh and Tipping, 1998; Smith, 1998). The evidence for slight changes in vegetation as seen in the previous chapter, coupled with the data of CFS presence shows there is possible low intensity activity in the surrounding area of Loch nan Eala, even if we are not seeing cereal pollen, whether this was associated with the crannog, or simply coincidental human activity, is unclear.

However, the lack of clear anthropogenic indicators such as cereal pollen, does not mean that there was no human activity on the landscape, as seen within the discussion, evidence of grazing, forest management and possible other agricultural indicators are found within the core. The sites seen locally and regionally from the Late Neolithic to the late Bronze Age are also reminders that the landscape was in constant use by people, in a full cycle of life within growing of food and grains as well as in death and funerary practices connecting the dead to the land.

As Dimbleby (1986) suggests, it is even more difficult interpreting a sequence of events in the pollen record when an occupation layer, like what we see at Loch nan Eala in the form of the crannog, lies on and covered by similar deposits. This is what we must take into account at Loch nan Eala, although the survival of the crannog shows clear archaeological evidence, the excavation dates to over a century ago, with little surviving evidence. It will be difficult or even unwise to dissect particular occupation layers related to human activity to explain its construction or date, as that may be projection rather than accurate interpretation. Whether this is tied to the crannog or not, it is likely linked to small scale anthropogenic activities of the local peoples living in the Loch nan Eala area at the time.

7.0 Conclusion

The study conducted at Loch nan Eala has successfully achieved many of the research aims set out in the previous chapter. Pollen data was recorded from 45 samples taken at a fine resolution of 1cm in order to create a reconstruction of the vegetation of the surrounding local area for the Late Neolithic to the end of the Bronze Age. The study has successfully produced a data set which can be linked to work by Shennan *et al*. (1994) to contribute to an important data set in a 'core area' of human activity, which was seen as previously missing (Carter *et al*., 2005). Non pollen palymorphs (NPP) and microcharcoal were also recorded and a data set has provided some key information regarding the influence of humans and animals in the Arisaig landscape. Evidence for human impact can be seen within the pollen record, although no evidence of agricultural related pollen was found within the samples. It was also confirmed that the pollen recorded in this data set cannot successfully provide answers to how Crannog 1 and 2 fit into the archaeological landscape. Although not all of the research aims could be completed, the project successfully contributed to further understanding of the Arisaig landscape, and how people in the past have created a visible footprint on the environmental record. It is important to highlight that there is large scope for future multidisciplinary work at the site of Loch nan Eala, which will be discussed in more detail below. Fine resolution at 1cm for this core could be critiqued as not as successful as previously hoped, the aim being to try to pick up clear signs of the crannogs and also signs of agriculture through the identification of cereal pollen, as Carter *et al.* (2005) show the presence of human activity through archaeological sites in the area. Although the lack of cereal pollen may simply be due to the site itself – considering work by Shennan *et al.* (1994,1995) also did not pick up cereal grain pollen at Loch nan Eala, or there being a lack of close pollinating crops growing close to the core location, but it is interesting to consider perhaps sample intervals of 0.5cm may have been more suited for these specific research aims. The limited samples examined within the study can also attribute to a limited reconstruction of the pollen record of LNE97-1, with a wider range of depths, would have shown a more rounded reconstruction. Unfortunately, the poor preservation of the lower depth pollen hindered the ability to record pollen below 200cm, having smaller intervals may have helped with this problem. The shallowest depth of the core is 154cm, with 1cm being lost to decomposition of the core, it would be advised that a study of the shallower depths of the core may further attribute to our knowledge of the environmental record occurring at Loch nan Eala. Counting TLP to 300 may also be critiqued as low for this study, this is something which can be improved in future studies, the differences in TLP quantities and the ability to produce strong data sets from these high pollen counts has been a valuable lesson for the author. The study would have also benefitted from Diatom analysis, as the fluctuations in water levels would have been better understood, it would have especially contributed to the understanding of salinity changes, which would help in understanding how it affected the vegetation changes. Diatom diagrams produced by Shennan *et al*., (1994) were useful in understanding some of the changes occurring in the Loch nan Eala area, although further analysis would be useful for further understanding environmental changes.

Although there is a lack of cereal pollen within this study, there is still the presence of agricultural attributed pollen such as *Artemisia,* Umbelliferae and *Rumex* as well possible Coprophilous fungal spores (CFS) such as *Arnium - type HdV 261/262* and *Sordaria-type HdV 55-A*, although the NPP evidence may be attributed to general decomposing of material (van Geel, 1978, van Geel *et al*., 1983b, van Geel *et al*., 2003, Ding *et al*., 2011, Baker *et al*., 2013, Davies, 2019). The sparsity of Neolithic and Bronze Age archaeological sites in the Arisaig and more regional area (see Tables 3 and 4) may indicate that during this time, the impacts of people on the landscape may have been less visible in comparison to the rest of the UK at the same time, focusing predominantly on small scale agricultural processes suited more for highland existence as suggested by Davies and Tipping (2004).

The environmental information from Loch nan Eala within this study, coupled with the evidence provided from Shennan *et al.* (1994), contributes to the local and regional reconstruction of the area over a large period of time and presents important information to the geographical and archaeological record. The pollen record itself illustrates how there are some dramatic changes in vegetation within the different zones, especially within the declines of tree pollen after 3749 Cal BP, with some rejuvenation hinting at forest management (see Figures 39 and 40). Activities such as coppicing of *Corylus* may be indicated by the peaks and dips seen throughout the pollen record, although as suggested by Waller *et al.* (2012), elements of natural changes in the environment may also have an effect in decreases/increases in pollen. From the end of LNE1/A to end of LNE1/B there is an overall dominance of tree pollen, which then appears steadily decline, perhaps reflecting a more regional decline of tree pollen beginning at 3749 Cal BP. This decline may also be due to more human agency in the landscape, making use of wood as a resource whilst the regeneration is not keeping up with human and perhaps climatic impact. Although core LNE97/1 and also cores from Shennan *et al* (1994) have not recorded high percentages of *Pinus* pollen, there was likely more *Pinus* in the area, as discussions with the *Pinus* pollen curve and pine macrofossils prove presence but almost never correlate (Selsing, 1999), there is still evidence of the Pine decline at 3749 Cal BP, with a further dip at 3566 Cal BP. The most dramatic decline in tree pollen seen in LNE2/A and into LNE2/B, especially around 3492 Cal BP, tree pollen falls to 15% according to the Age Depth model (Figure 42). Similar trends may be reflected in pollen records of the surrounding sites such as Allt Dail an Dubh-asaidh (see Carter *et al*., 2005) suggesting the decline may have resulted from a combination of climate and environmental change, as well as some small-scale human impact such as grazing, deforestation and forest management, a theory which is likely also seen at Loch nan Eala and supported by Shennan *et al*. (1994) and Carter *et al*. (2005) for the surrounding Arisaig area. A rise in shrub pollen especially within LNE2/A and LNE2/B, around 3342 Cal BP, shrub pollen dominates at 80% and tree and herb pollen fall to around 10% each (see Figures 39 and 40). The most dramatic rise in herb pollen in LNE2/A at 3492 Cal BP and LNE4 2868 – 2810 Cal BP, coupled with the NPP data suggesting *Eriophorum* (see Figure 39 and 40), may suggest a move to a wetter climate with LNE4 dating to the end of the Bronze Age, a period of local and regional environmental change (e.g., Dubois & Ferguson 1985, Gear & Huntley 1991). Other NPP evidence in the form of Coprophilous fungal spores (CFS) such as *Arnium - type HdV 261/262* and *Sordaria-type HdV 55-A*, were noted and when coupled with evidence of species related to anthropogenic disturbance such as *Artemisia,* Umbelliferae and *Rumex*, it is often indicative of grazing activity in the past, which is likely occurring in the catchment area around Loch nan Eala (van Geel, 1978, van Geel *et al*., 1983b, van Geel *et al*., 2003, Ding *et al*., 2011, Baker *et al*., 2013, Davies, 2019). The pollen record also has 3 radiocarbon dates which can be added to the previous dates produced by Shennan *et al.* (1994) (see Figures 42 and 44), and can be used in collaboration to further research areas of sea level changes in the Loch nan Eala basin. The pollen record does seem to reflect the areas of marine isolation from the lack of *Plantago maritima*, suggesting a lack of salinity in the water, the isolation data presented by Shennan *et al* (1994) matches the pollen seen within core LNE97/1.

Much of the earlier evidence for human activity in the western highlands is found within unstratified or from disturbed contexts (see Tables 3 and 4) (Carter *et al*., 2005, Canmore, 2022), there needs to be a greater amount of ^{14}C dating from archaeological investigations to provide a better chronology of anthropogenic impact in the area. Human activity, although possible to discern in the pollen record, could also have been masked by natural vegetation successions and declines missed within this study. Land use in the highlands of Scotland is thought to be managed on a smaller more intensive scale (Davies and Tipping, 2004) and this can be seen in Arisaig with distinctive patterns of low intensity land use appearing common in the peripheral areas and extensive sites of land use appear to be repeatedly reused (Carter *et al.,* 2005:27). Although no cereal pollen was found at the site, this does not prove that cereal was not there (Edwards *et al.*, 2005, Davies, 2007, Tipping *et al*., 2009, Innes *et al*., 2010, Bishop *et al*., 2015), small scale activity such as grazing was likely presented within the pollen record through the apparent trends of vegetation changes and NPP data found within the pollen record. Shennan *et al.* (1994) also mention that there was only possible small scale human impact on in the area seen within the pollen record. Research frameworks by RARFA (ScARF, 2017), in particular Agendas 3.7, have pressed the importance for of more collaborative work between archaeologists and scientists involving the environmental reconstruction of the Morar area, which this study has aimed to contribute towards.

Although a 1cm fine resolution palynological data set has been produced for Loch nan Eala, the attempt in identifying Crannog 1 within the pollen record was unsuccessful. The disjunction between the excavation of Crannog 1 in 1856 (Mapleton, 1870) to the present day has resulted in a large amount of data to being lost, and it would be unwise to match any trends in pollen data within this study to the crannogs without further datable evidence. Although there are clear signs of small-scale human activity in the Loch nan Eala area, without having a date associated with the crannog, it is unclear when it was in use. As Tipping (1994) states, the importance of coupling palynological data with other macro evidence is the only way for us to realistically build a picture of the past. This study demonstrates that there is large scope for further archaeological investigation of Loch nan Eala and the crannogs located there. A mixture of further palynological investigation at perhaps a smaller <1cm interval set, coupled with sampling strategies within the crannogs to provide a core taken closer to the site, as well as grab samples taken for plant macro, beetle, mollusc, charcoal and artefact evidence would provide a substantial data set to compare the pollen data to. In particular, archaeobotanical evidence provided by the sampling strategy would help in furthering any dating evidence which could be submitted for ^{14}C dating and provide information on the possible diet of the peoples there. The overall count of charcoal was low within the pollen record at Loch nan Eala, it could be argued that there may have been some user error with the point count method applied to this methodology, so it would be useful to determine the presence of charcoal at the site itself from environmental samples being taken at various locations near the crannog and determine whether a charcoal assemblage is present. The identification of charcoal down to species level would also be useful to determine what plant species was being engaged with at Crannog 1, as Mapleton (1870) notes signs of burning on the stone slabs, this could be compared to pollen data to see if a certain species was being favoured by humans at that time. It is unfortunate that COVID19 has caused limitations in project designs as well as material available for assessment. As crannogs 1 and 2 are undated this means there is a limitation in comparison to the pollen record, ^{14}C dating would provide much greater insights into where they tie into the regional landscape of human activity, contributing important information into the understanding of crannog construction in Arisaig and even Scottish history, as crannog construction and use are still often debated (Garrow and Strut, 2019). It is also suggested that further investigation of the crannogs through survey, excavation and underwater investigation is highly recommended and would contribute knowledge of local, regional and national importance. With the COVID19 lockdown restrictions lifted in 2022, a small self-funded field walk was conducted, in attempt to locate the Crannogs and see if any positive archaeological evidence remained. Unfortunately, both crannogs were not visible on the ground, as layers of turf had sealed Crannog 2, and Crannog 1 was located underwater, so no further information was found or assessment could be made, the site does not currently have approval for excavation, so only visual evidence was sought. An excavation of the crannogs would likely help to illuminate the type of features they may be, as suggested in the literature review, they have been deemed 'Crannogs'

(Mapleton, 1870, HRC, 1986). Underwater analysis of the loch by scuba diving can determine whether any artefacts were deposited within the loch, typically a common characteristic feature of crannogs (Garrow and Strut, 2019). With the presence of datable evidence, the pollen record presented within this study and the work done by Shennan *et al*. (1994) could then be compared to any new evidence found, which may illuminate areas of anthropogenic activities and play into the local and regional narrative. Research frameworks in Argyll by RARFA (ScARF, 2017), in particular, Agendas 3.4 has also expressed a need for further collaboration between archaeological fieldwork and environmental reconstruction, suggesting there is great scope for further investigation of archaeological sites such as Crannog 1 and 2 at Loch nan Eala, with at least an assessment report accessible to the public through the ADS and OASIS.

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9.0 Appendix

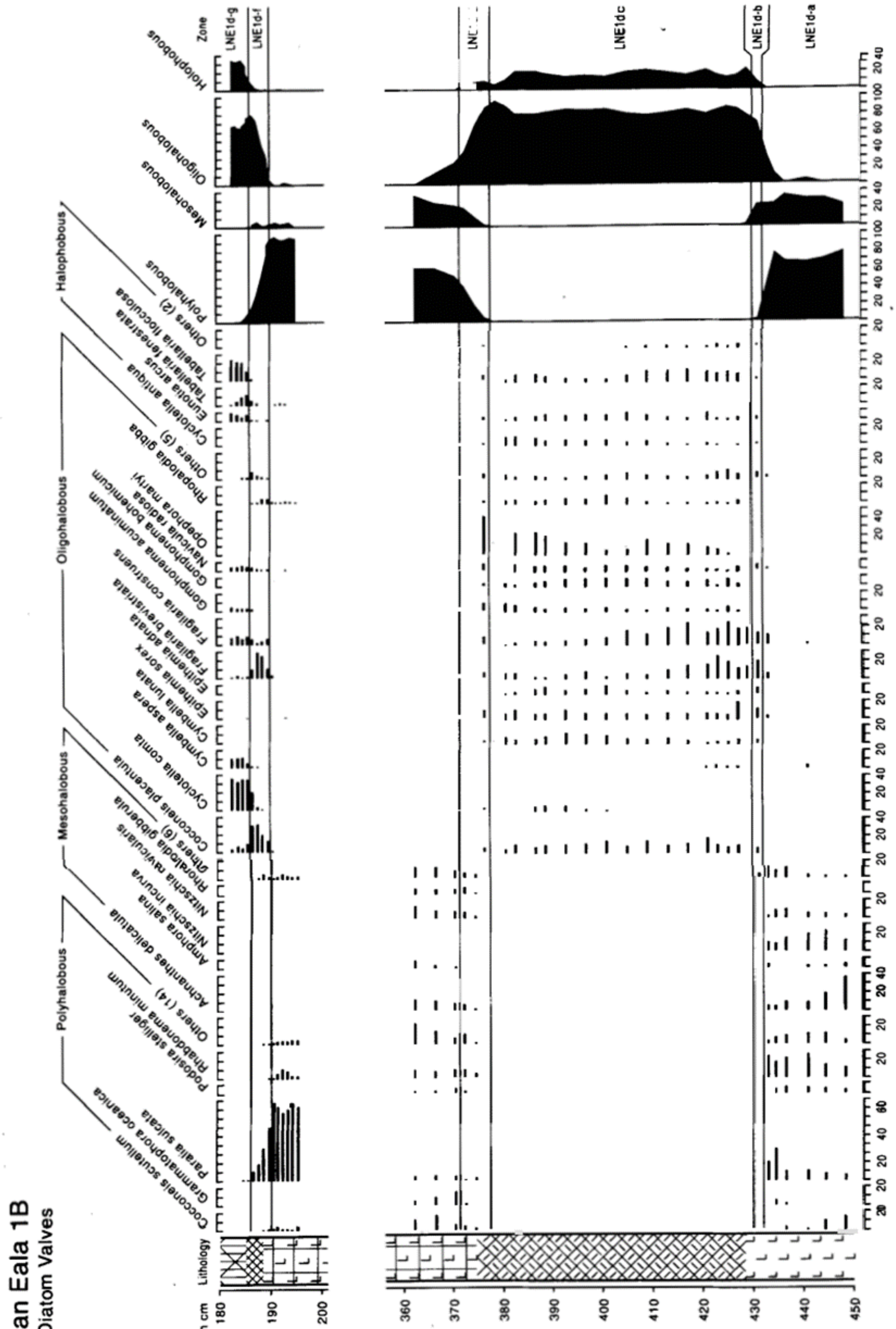

Figure 46 Loch nan Eala, total percentage Diatom valves (Shennan et al., 1994)

Mai Walker
University of Durham

^{14}CHRONO Centre
Queens University
Belfast
42 Fitzwilliam
Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-46260
Date of Measurement:	2021-12-01
Site:	Loch Nan Eala 97
Sample ID:	LNE97/155
Material Dated:	peat (bulk)
Pretreatment:	Acid Only
mg Graphite:	0.993
Submitted by:	Mai Walker

Conventional ^{14}C Age:	2714±26 BP
Fraction corrected	using AMS δ^{13}C

Figure 47 Radiocarbon Date Certificate for Sample: LNE97/155 (Reimer et al., 2020)

Mai Walker
University of Durham

Queen's University Belfast
14CHRONO
Centre for Climate, the Environment, and Chronology

^{14}CHRONO Centre
Queens University
Belfast
42 Fitzwilliam
Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-46261
Date of Measurement:	2021-12-01
Site:	Loch Nan Eala 97
Sample ID:	LNE97/176
Material Dated:	peat (bulk)
Pretreatment:	Acid Only
mg Graphite:	0.983
Submitted by:	Mai Walker

Conventional ^{14}C Age:	3148±31 BP
Fraction corrected	using AMS δ^{13}C

Figure 48 Radiocarbon Date Certificate for Sample: LNE97/176 (Reimer et al., 2020)

Mai Walker
University of Durham

Queen's University Belfast
14CHRONO
Centre for Climate, the Environment, and Chronology

^{14}CHRONO Centre
Queens University Belfast
42 Fitzwilliam Street
Belfast BT9 6AX
Northern Ireland

Radiocarbon Date Certificate

Laboratory Identification:	UBA-46262
Date of Measurement:	2021-12-01
Site:	Loch Nan Eala 97
Sample ID:	LNE97/196
Material Dated:	peat (bulk)
Pretreatment:	Acid Only
mg Graphite:	0.304
Submitted by:	Mai Walker

Conventional ^{14}C Age:	4225±48 BP
Fraction corrected	using AMS δ^{13}C

Figure 49 Radiocarbon Date Certificate for Sample: LNE97/196 (Reimer et al., 2020)

Marine samples will require re-calibration with the marine calibration curve

```
 3
              RADIOCARBON CALIBRATION PROGRAM*
                        CALIB REV8.2
         Copyright 1986-2020 M Stuiver and PJ Reimer
 *To be used in conjunction with:
 Stuiver, M., and Reimer, P.J., 1993, Radiocarbon, 35, 215-230.

UBA-46260
46260
Radiocarbon Age BP   2714 +/-   26
Calibration data set: intcal20.14c               # Reimer et al. 2020
  % area enclosed       cal AD age ranges            relative area under
                                                 probability distribution
  68.3 (1 sigma)     cal BC 898- 866                     0.522
                            849- 820                     0.478
  95.4 (2 sigma)     cal BC 907- 810                     1.000
  Median Probability:  -861

UBA-46261
46261
Radiocarbon Age BP   3148 +/-   31
Calibration data set: intcal20.14c               # Reimer et al. 2020
  % area enclosed       cal AD age ranges            relative area under
                                                 probability distribution
  68.3 (1 sigma)     cal BC 1493- 1480                   0.129
                            1452- 1398                   0.854
                            1331- 1328                   0.017
  95.4 (2 sigma)     cal BC 1499- 1382                   0.893
                            1341- 1312                   0.107
  Median Probability: -1427

UBA-46262
46262
Radiocarbon Age BP   4225 +/-   48
Calibration data set: intcal20.14c               # Reimer et al. 2020
  % area enclosed       cal AD age ranges            relative area under
                                                 probability distribution
  68.3 (1 sigma)     cal BC 2902- 2858                   0.414
                            2806- 2752                   0.450
                            2721- 2702                   0.136
  95.4 (2 sigma)     cal BC 2915- 2833                   0.378
                            2820- 2664                   0.603
                            2650- 2633                   0.018
  Median Probability: -2792

 References for calibration datasets:
Reimer P, Austin WEN, Bard E, Bayliss A, Blackwell PG, Bronk Ramsey C, Butzin M
Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg A
Kromer B, Manning SW, Muscheler R, Palmer JG, Pearson C, van der Plicht J, Reim
Richards DA, Scott EM, Southon JR, Turney CSM, Wacker L, Adolphi F, BÃ¼ntgen U,
Fahrni S, Fogtmann-Schulz A, Friedrich R, KÃ¶hler P, Kudsk S, Miyake F, Olsen J
Sakamoto M, Sookdeo A, Talamo S. 2020.
The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0-55 cal kB
Radiocarbon 62. doi: 10.1017/RDC.2020.41.


Comments:
* This standard deviation (error) includes a lab error multiplier.
** 1 sigma = square root of (sample std. dev.^2 + curve std. dev.^2)
** 2 sigma = 2 x square root of (sample std. dev.^2 + curve std. dev.^2)
where ^2 = quantity squared.
[ ] = calibrated range impinges on end of calibration data set
0* represents a "negative" age BP
1955* or 1960* denote influence of nuclear testing C-14
```

Figure 50 Dataset provided from Radiocarbon Dating from Queens University (Reimer et al., 2020)