Finding Common Ground:

A Plant Macrofossil-Based Palaeoenvironmental Investigation of Early Prehistoric Horizons at the Bay of Ireland, Orkney, UK

Carly Henkel

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Dr. M.H. Field
Specialization: Archaeobotany
University of Leiden, Faculty of Archaeology
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Contents

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Chapter 1:
Introduction

This thesis comprises a palaeoenvironmental investigation of late Mesolithic to early Neolithic sediment horizons from the Orkney Isles. The present chapter provides background information regarding the changing environmental context of northern Scotland during the Holocene, with particular reference to Orkney. It also discusses the use of pollen and macrofossil proxies in palaeoenvironmental research, as well as outlines the specific aims and objectives of the present investigation. The chapter concludes with a brief mention the conventions used throughout the thesis and an introduction to the study site on Mainland Orkney.

1.1 HOLOCENE BACKGROUND OF ORKNEY

The Holocene comprises the current interglacial period that we live in today. It began c. 11,700 years ago, after the last ice age, and initiated significant changes to climate, vegetation, human habitation, and sea-level rise. How these changes interrelated and impacted one another greatly influenced palaeoecologies throughout the Holocene. In order to fully understand Orkney's prehistoric environment, it is thus necessary to comprehend the dynamic processes that created the conditions under which it developed.

The glacial period prior to the Holocene is known as the Late Devensian (c. 26,000 – 10,000 BP) (Ballantyne and Dawson 2003, 27). This period was characterized by extremely cold temperatures and glacier formation, which covered most – if not all – of Scotland. Estimates for the limits of the Scottish ice sheet at this time vary. Some researchers believe that northern-most Scotland escaped glaciation, while others maintain that glacial coverage in Scotland included the Orkney Isles (Figure 1.1) (Ballantyne and Dawson 2003, 27; Ballantyne 2004, 27-28; Wickham-Jones and Firth 2000, 120). Though deposits of glacial till on Orkney attest to its glaciation in the past, it remains uncertain whether this ice-cover occurred during the Late Devensian or an earlier glacial period (Ballantyne 2004, 27). Nevertheless, even if Orkney remained ice-free during at this time, proximity to the ice sheet would have rendered the area largely inhospitable due to extremely cold temperatures and a prevailing tundra-like environment (Edwards 2004, 56; Wickham-Jones and Firth 2000, 121).

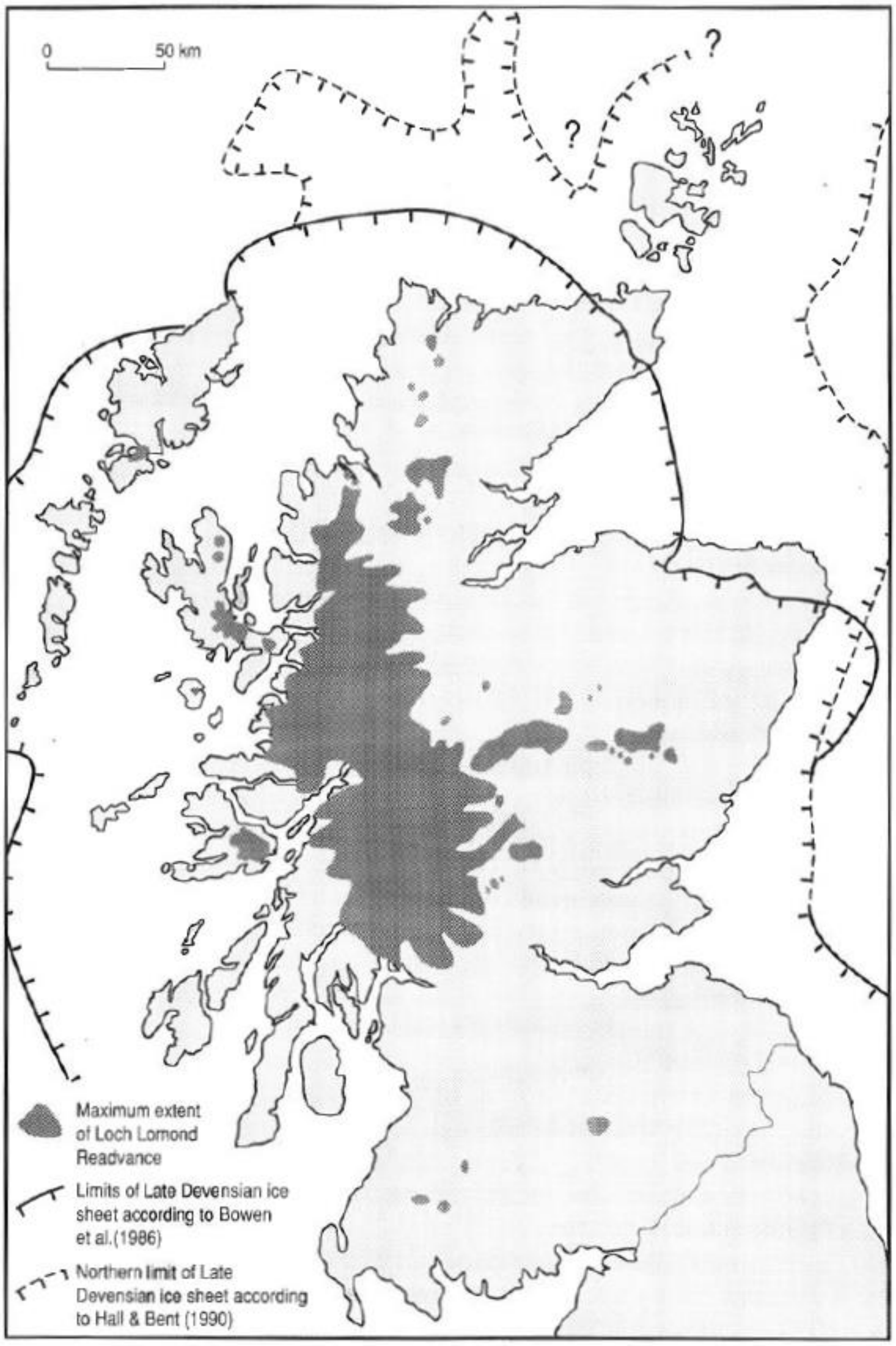


Figure 1.1: Debated northern limit of the Late Devensian Scottish ice sheet (Ballantyne and Dawson 2003, 28).

By the beginning of the Holocene, however, climate amelioration had begun to melt the ice sheet, causing its retreat. Vast areas of Scotland's landscape became available for recolonization by biota as the glacier receded to the upper reaches of the Scottish Highlands (Wickham-Jones and Firth 2000, 121). While researchers once believed that climatic warming at the end of the Last Ice Age consisted of a gradual process that transpired over several centuries, more recent studies have proven that climate amelioration occurred rapidly, over mere decades (Ballantyne 2004, 30; Edwards and Whittington 2003, 64; Warren 2005, 45-46). By the beginning of the Mesolithic Period (c. 9,000–4,000 BC), mean summer temperatures were reaching several degrees higher than today's, making areas of northern Scotland, including Shetland and Orkney, once again suitable for habitation (Wickham-Jones and Firth 2000, 119).

At that time, the early Holocene coastline of the British Isles looked vastly different than their current configuration. Lower sea-levels, caused by previous glacier formation, had exposed areas of low-lying land and as a result, the Britain still formed part of the continental landmass (Edwards 2004, 55). The area now occupied by the North Sea consisted of a large alluvial plain known as 'Doggerland' that connected the low countries of north-western Europe to Britain (Edwards 2004, 55; Wickham-Jones 2014, 696). Likewise, both Orkney and Shetland comprised part of the Scottish mainland in the North (Figure 1.2) (Edwards 2004, 55-56). Thus, early floristic and human communities easily migrated up into the northernmost reaches of Scotland via the South, from Britain, and via the East, from continental Europe (Birks 1989 521-522; Tipping 1994, 9; Whittington and Edwards 2003, 14).

The development of Scotland's post-glacial vegetation consisted primarily of tree taxa, creating a wood-dominated environment from the Mesolithic period onwards (Edwards and Whittington 2003, 64). The spread of tree taxa, however, did not consist of an even northward movement of mix woodland. The northern establishment of trees was dictated by a complex combination of factors which facilitated different tree taxa at different times (Birks 1989 530). While the rapid warming of temperatures created suitable climatic conditions throughout Scotland for most tree types, a lag occurred between early Holocene climate amelioration and the establishment of woodland trees in the North (Tipping 1994, 9). Glacial refugia locations, the number of years before seed production, varying seed dispersal mechanisms, soil development, and competition between taxa all comprised elements that contributed to the varying temporal and spatial migration of prehistoric trees (Edwards and Whittington 2003, 67; Tipping 1994, 9-10).

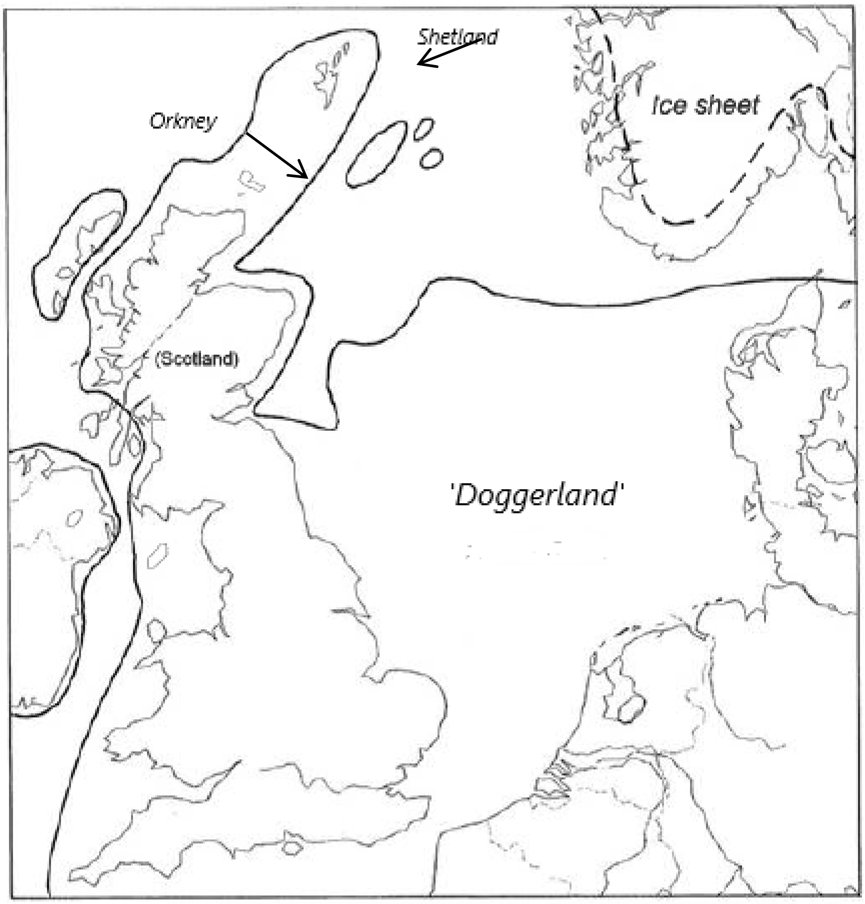


Figure 1.2: Land configuration for north-western Europe c. 12,000 BP (after Edwards 2004, 56).

Based on 135 securely dated pollen profiles, Birks (1989) created isochrones maps for the Holocene pattern and spread of major woodland tree taxa in the British Isles. These maps "provide *minimal* estimates of the timing of tree arrival following deglaciation" (Birks 1989, 506). *Betula* (birch) and *Corylus* (hazel) constitute early tree colonizers of Scotland, reaching northern locations, such as Orkney, soon after climate amelioration (Birks 1989, 507-509; Tipping 1994, 10; Warren 2005, 53). *Ulmus* (elm) and *Quercus* (oak) arrived later, towards the latter end of the Mesolithic (Birks 1989, 511; Edwards and Whittington 2003, 65-66), while *Alnus* (Alder) and *Pinus* (Pine) constitute late colonizers, not spreading to northern areas of Scotland until the Neolithic period (c. 4,000-2,000 BC) (Birks 1989, 514; Tipping 1994, 10). While Birks' maps possibly require revision, due to thirty years of additional data collection since their creation (Whittington and Edwards 2003, 16), they still provide a general understanding of post-glacial vegetation development throughout Britain and Scotland.

Climatic amelioration after the ice age also allowed for the recolonization of the British Isles by humans. Scarce evidence exists for anthropogenic habitation in Scotland during the Late Upper Palaeolithic (13,000-9,000 BC); only a couple of flint tools hint at a limited human presence in Scotland at this time (Saville 2000, 91-92; Woodward 2007, 2). Some of these lithics were discovered in Orkney (Saville 2000, 93; Woodward 2007, 2), which attest to northern exploration by humans soon after glacier disappearance. These artefacts, however, may not reflect settlement of northern areas, but rather the hunting range of Late Upper Palaeolithic communities (Edwards 2004, 56), for the post-glacial tundra-like environment of Scotland offered little attraction for settlement. By the 8th millennium BC, however, evidence for Mesolithic sites across Scotland suggests a rapid recolonization of the area (Wickham-Jones and Firth 2000, 127). Since the Mesolithic lifestyle relied heavily on woodland resources, it is believed that early hunter-gatherers of this period lived within or in close proximity to the developing forests and thus, presumably settled Scotland by following the northward movement of the woodland treeline (Edwards 1982, 16; Warren 2005, 66 & 72).

Later in the Mesolithic period, hunter-gatherer settlement patterns in Scotland show a clear shift towards the coastal zone (Mellars 2004, 171-172; Wickham-Jones 2014, 700). The sea offered a wealth of economic resources and provided an easier means of travel and communication (Dawson et al. 2009, 3; Mellars 2004, 172). Additionally, the ready supply of marine resources reduced subsistence risk for Mesolithic communities, allowing them to remain in an area even after the seasonal depletion of edible woodland resources (Mellars 2004, 171-172). It seems likely, therefore, that prehistoric hunter-gatherers would have inhabited Orkney as part of this later Mesolithic preference for coastal settlements.

Interestingly, Mesolithic communities started to become coastal dwellers during a rather unstable period for the Scottish coastlines. As the Scottish ice sheet reduced in size, towards the end of the Late Devensian, the amount of weight upon the land lessened, causing uplift of the landscape (Ballantyne and Dawson 2003, 33). At the same time, the additional water from the melting glacier also caused an overall rise in sea-levels (Ballantyne and Dawson 2003, 33). The rates at which these two phenomena occurred impacted various parts of the Scottish landscape at different times (Ballantyne 2004, 35-36). Since ice volume is greatest, and therefore heaviest, at its core (Ballantyne 2004, 35; Warren 2005, 48), the greatest uplift in the landscape occurred in the area around Ranoch Moore – the epicentre for the formation of the last Scottish glacier (Ballantyne and Dawson 2003, 33; Warren 2005, 47). Extending outward from this point, isosatic rebound affected the landscape to lesser degrees and in north-eastern Scotland, Orkney experienced very little – if any – uplift of landmass (Warren 2005, 48).

While land surface uplift and sea-level rise occurred simultaneously, the rate of land surface rebound initially surpassed the relative rate of sea-level rise (Warren 2005, 47). Once uplift rates slowed, sea-level rise began to impact the landscape more drastically, causing vast stretches of the coast to become inundated and permanently submerged under water (Warren 2005, 47). Since areas furthest from the centre of ice formation experience relatively little uplift, these areas were greatly subjected to the effects of sea-level rise (Ballantyne and Dawson 2003, 33 & 37). In the north-east, land encroachment by the sea had already caused the early separation of Shetland and Orkney from the Scottish mainland (Davidson and Jones 1985, 15). Constant sea-level rise through the early Holocene continued to widen this distance between these newly formed islands and the mainland. At the same time, the North Sea inundated the area of Doggerland in the south-east, effectively severing Britain from mainland Europe (Ballantyne 2004, 35; Edwards 2004, 58; Wickham-Jones 2014, 696). These alterations to the landscape disrupted vegetation transport routes, effectively sequestering Orkney's flora from the rest of Scotland and Britain's flora from the rest of Europe.

Even after Orkney's initial separation from northern Scotland, research estimates that the Orcadian landscape was more extensive than it is today – comprising a connected landmass as opposed to an archipelago (Buhat 2018, 4-5). As sea-levels continued to rise, it submerged more of the Orcadian coastline and formed the series of islands, known today as the Orkney Isles (Figure 1.3) (Ballantyne and Dawson 2003, 40). In fact, research estimates that relative sea-levels around Orkney rose dramatically throughout its early prehistory (roughly 10-14 m, depending on the area), then slowed to reach their current level towards the end of the Neolithic period (Bates and Nayling 2013, 26; Wickham-Jones and Firth 2000, 121). As a result of this rise, the prehistoric coastlines of Orkney and much of northern Scotland now lay many metres beneath the sea (Bates and Nayling 2013, 25-27). Since hunter-gatherer communities demonstrated a later affinity for coastal settlements, much of the Mesolithic archaeological landscape, including sites and evidence of Mesolithic activity, were also submerged (Bates and Nayling 2013, 26-27; Warren 2005, 49).

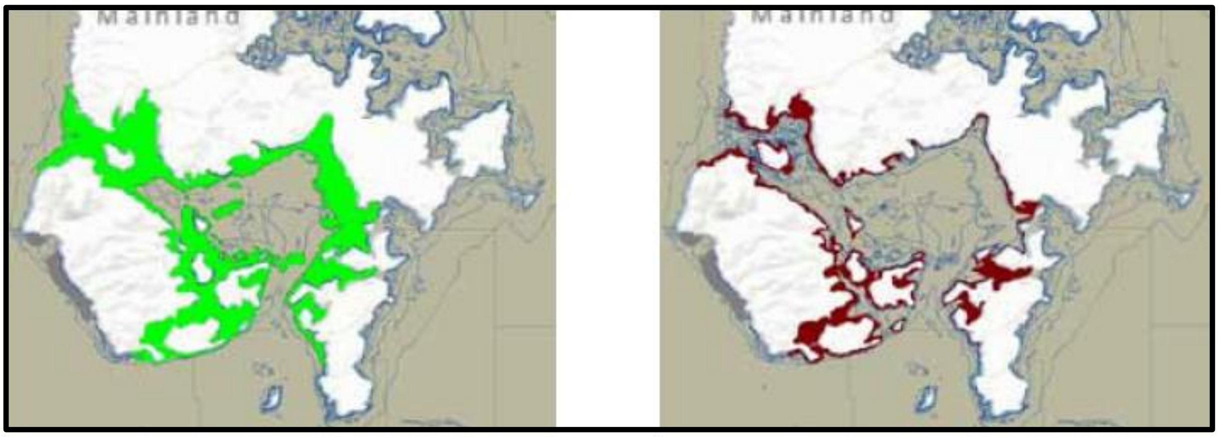


Figure 1.3: Reconstruction of Holocene inundation for the Orkney Iles. Left: As a more collective landmass during the early Mesolithic; Right: As more of an archipelago during the early Neolithic (Bates et al 2011, 7).

Melting glaciers may have also had an impact on Scottish weather patterns. The circumpolar vortex, an important climatic mechanism, circles the North Pole at a slightly higher latitude than Scotland (Whittington and Edwards 2003, 12). The addition of glacier melt-water to the ocean disturbs forces, such as the Polar Front and the Gulf Stream, which regulate its usual position (Ballantyne 2004, 30). Such disturbances create a depression in the vortex's movement (Figure 1.4), causing Scotland to experience strong winds and increased precipitation (Whittington and Edwards 2003, 12). Thus, while traditional divisions of the Holocene are based on periods of generalized climate (Table 1.1), different weather patterns still occurred on a national and regional scale (Whittington and Edwards 2003, 20). Scotland's proximity to the Polar Front has rendered it particularity susceptible to unfavourable weather conditions despite an overall temperate climate.

Thus, the interrelationship between climate change, vegetation development, human settlement, and sea level rise are important considerations for palaeoenvironmental reconstructions of sites dating to the Holocene; for one or more of these elements may have played a significant role in determining the conditions in which local ecologies developed. An informed interpretation of a past environment therefore requires an understanding of the processes that facilitated its establishment in the first place.

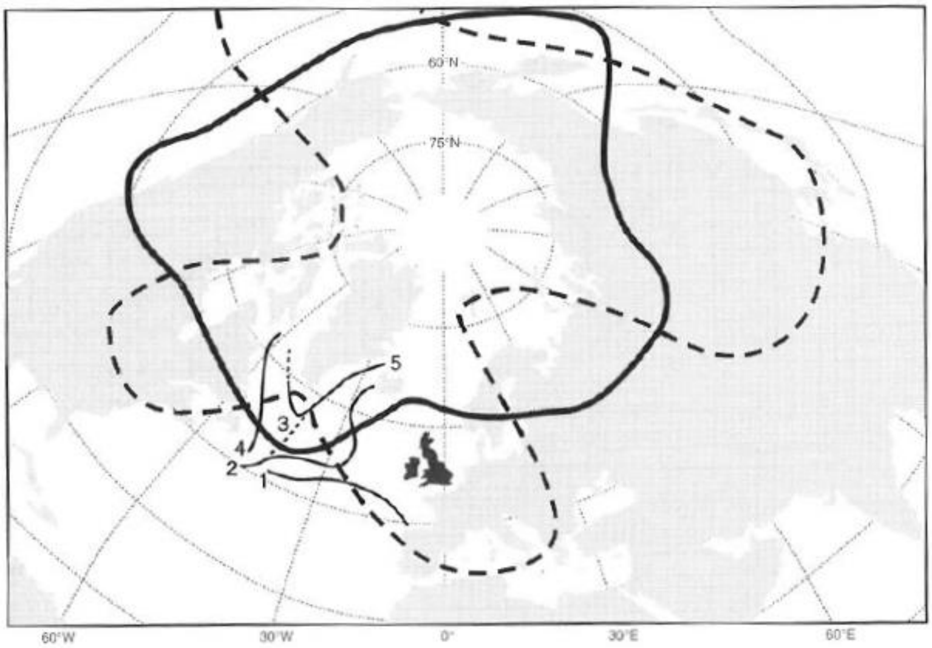
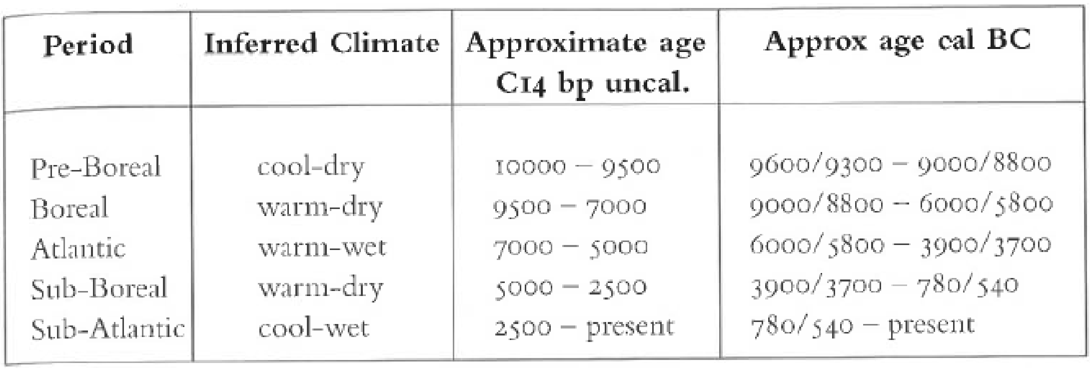


Figure 1.4: Climate mechanisms affecting Scottish weather. The solid line represents the usual path of the circumpolar vortex and the dashed line shows the altered depression of the path as a result of disturbances, such as movement of the Polar Front (Whittington and Edwards 2003, 12).

Table 1.1: Traditional climate-based Holocene divisions (Warren 2005, 47).



Period	Inferred Climate	Approximate age C14 bp uncal.	Approx age cal BC
Pre-Boreal	cool-dry	10000 – 9500	9600/9300 – 9000/8800
Boreal	warm-dry	9500 – 7000	9000/8800 – 6000/5800
Atlantic	warm-wet	7000 – 5000	6000/5800 – 3900/3700
Sub-Boreal	warm-dry	5000 – 2500	3900/3700 – 780/540
Sub-Atlantic	cool-wet	2500 – present	780/540 – present

1.2 PALAEOENVIRONMENTAL PROXIES: PALYNOLOGY VS. MACROFOSSIL ANALYSIS

To date, most regional and local palaeoenvironmental investigations of post-glacial vegetation development in the British Isles are largely based on palynology (Edwards and Whittington 2003, 63). For example, Birks' isochrone maps detailing the regional spread of tree taxa after the Last Ice Age were generated exclusively from the results of pollen analysis; omitting all independently obtained macrofossil data for tree presence (Birks 1989, 506). While pollen analysis constitutes a relatively suitable methodological approach to studies of regional vegetation distribution, palynology also forms the basis of most local vegetation studies in the British Isles. The study of Orkney's palaeoenvironment is overwhelmingly dominated by pollen-based research. Very few investigations (de la Vega-Leinert et al. 2012; Timpany et al. 2017; Whittington et al. 2015) consider other palaeoenvironmental proxy evidence.

Unlike regional studies, pollen analysis is less suitable for local investigations of past vegetation due to its methodological limitations. Firstly, pollen analysis often cannot provide species-level identifications for many plant taxa (Edwards and Whittington 2003, 64). Detailed ecological interpretations, however, require species identifications, since various plant species within a single genus may have different ecological tolerances. For example, while all species of the *Juncus* genus indicate a damp local environmental, *Juncus gerardii* constitutes a halophytic species which can tolerate rather brackish growing conditions, whereas *Juncus articulatus* prefers a freshwater environment. Hence, without plant species identifications detailed ecological aspects of past environments may remain missing from palaeoenvironmental interpretations.

Secondly, the interpretation of pollen values can prove problematic, especially concerning the local presence of tree taxa. While research suggests that trees may remain palynologically silent during their initial arrival and establishment in a new area (Whittington and Edwards 2003, 15), it has also been proposed that low pollen values may denote this early phase of tree spread (Birks 1989, 506). Conversely, low pollen tree taxa values are also often interpreted as the result of long-distance transport (Birks 1989, 506), since certain tree pollen, such as *Pinus* (pine), is known to travel great distances via the wind (Edwards and Whittington 2003, 64). In fact, the issue of long-distance transport remains central to uncertainties regarding the native status of prehistoric tree taxa in the Orkney Isles. When considering the latitudinal limits of ancient woodland spread, Tipping (1994, 13) states that "the local presence of tree species on palynological criteria, but unsupported by wood remains, must remain conjectural. Interpretations rely on percentage-based pollen counts, and are essentially subjective assessments." In other words, the use of additional methodological approaches, which can provide unequivocal evidence for the local presence of tree taxa, are required in conjunction with pollen analysis in order to firmly establish site ecologies – especially in marginal areas where pollen values may be subject to doubt.

Evidence from plant macrofossil remains presents a ready solution to both of the above-mentioned palynological issues. Seeds, tree stumps and root systems often remain close to their original area of growth (Edwards and Whittington 2003, 64). Therefore, their remains attest to the local growth of the flora they represent. Certain macrofossils, such as the seeds and fruits of plant taxa, also readily facilitate species-level identifications, providing greater ecological specificity of the local vegetation. Unfortunately, wood remains – like pollen analysis – are mostly restricted to genus-level identifications, but the distinct morphological characteristics of seeds and fruits often denote specific plant species. Thus, pollen analysis is best employed in conjunction with additional palaeoenvironmental proxies, such as plant macrofossil evidence, in order to obtain a more comprehensive understanding of past vegetational environments.

1.3 PURPOSE OF THIS STUDY

This thesis research entails a plant macrofossil analysis of late Mesolithic and early Neolithic sediment horizons associated with the rare remains of a submerged forest on Mainland Orkney. The study acts as part of an on-going multidisciplinary investigation of this Orcadian site, which utilizes results from various palaeoenvironmental proxies in order to reconstruct Orkney's prehistoric environment. A previous study analysed pollen, non-pollen palynomorphs, and waterlogged plant remains from an earlier period in the site's overall stratigraphic sequence (c. 4,600 – 4,410 cal BC) (Timpany et al., 2017). The analysis presented here extends this stratigraphic investigation into Orkney's palaeoenvironment (c. 4,589 – 3,596 BC) and provides plant macrofossil evidence for these later prehistoric horizons.

The results of the present plant macrofossil analysis will not only contribute to current palaeoenvironmental research on Orkney, but will also compliment past and future Orcadian pollen studies by providing better insight into the local vegetational ecology, as well as producing secure identifications of prehistoric woodland components.

1.4 AIMS AND OBJECTIVES

The overall aim of the present thesis research is to generate a plant macrofossil-based palaeoenvironmental reconstruction of early prehistoric Orkney. Since the sediment sequence under analysis spans an important transitional period in history

– late Mesolithic to early Neolithic – which is characterized by an increase in anthropogenic activity and a change in climatic conditions, research objectives include the following:

- To determine the vegetational ecology of the immediate area during the late Mesolithic to early Neolithic periods.
- To investigate the local presence of tree taxa.
- To identify any changes in vegetation composition over time.
- To discern potential cause(s) for vegetation succession, such autogenic, climatic, or anthropogenic factors.
- To assess the quality of the macrofossil data via comparison with previous palynological investigations of Orkney's palaeoenvironment.

1.5 CONVENTIONS

In this thesis, early Orcadian prehistory encompasses the Late Upper Palaeolithic, Mesolithic and Neolithic periods. Dates for these prehistoric periods follow those outlined by Farrell (2009). References to 'early' or 'late' parts of prehistoric periods equate to the first or second half of those timespans based on mid-points for the period ranges. For example, as outlined by Farrell et al. (2015, 226), the Orcadian Neolithic spans from c. 4,000-2,000 BC, thus 'early Neolithic' refers to 4,000-3,000 BC and 'late Neolithic' refers to 3,000-2,000 BC. As much as possible, all dates are presented in years BC, except in cases where a BC dates is not available and an absolute date is necessary. In such situations, dates are given in the manner provided by the cited author, since a computer program for date conversion was not available to create to consistent presentation of date ages. Additionally, plant nomenclature and habitat ecologies follow Stace (1997).

1.6 THE STUDY AREA

The Orkney Isles make an excellent study area for palaeoenvironmental investigation due to its marginal geographical position and rich archaeological history. It offers both the possibility to examine vegetational ecologies in an extreme northern location and to investigate the extent to which climate change, sea-level rise, and prehistoric communities may have impacted this vegetation over the past several millenia.

Orkney constitutes an archipelago located 16 km off the northern coast of Scotland in the North Sea (Whittington et al. 2015, 113). Prior to post-glacial inundation, these islands comprised a plateau of gently rolling hills and a single massif (Davidson 1979, 7). Today, sea level rise has mostly transformed the plateau into a series of low-relief islands, with the exception of Hoy, which features the elevated terrain of the ancient mountain ridge (Figure 1.5). Mainland Orkney, the largest of the group of islands, lies near to the centre of the archipelago and accounts for more than half of the islands' collective land mass (Davidson and Jones 1985, 10).

Due to oceanic influences, the modern Orcadian climate is temperate (Davidson and Jones 1985, 17). Temperature readings over a ten-year period from Kirkwall airport on the Mainland indicate a winter mean of 3.8 °C in February and a summer mean of 12.8 °C in July (Davidson et al. 1979, 7). Despite moderate temperatures, the Orkney Isles are characterized by unfavourable weather conditions, including frequent clouds, fog, precipitation, strong winds and wave action (Bates and Nayling 2013, 26; Davidson et al. 1979, 10). In fact, gales are a common feature of Orcadian weather, especially in the winter (Davidson and Jones 1985, 17). In 2013, a severe storm caused coastal erosion at the head of the Bay of Ireland, which lies along the south coast of western Mainland (Figure 1.6 A), roughly 2.6 km from the town of Stromness (Timpany et al. 2017, 2). The erosion revealed an oak plank and the remains of a submerged forest embedded within an exposure of intertidal peat. These remains quickly became the focus of palaeoenvironmental investigations and the site comprises the study location for this thesis research.

The Bay of Ireland site is located along the inner shores of the bay, just south-west of a channel which acts as the outflow for the Loch of Stenness (Figure 1.6 B). Analysis of the submerged forest revealed that the woodland remains comprise the remnant stumps of *Salix* and *Betula* trees (Timpany et al. 2017, 4). A gouge auger transect determined that these woodland remains stretch for roughly 20m within a large area of peat (Timapny et al. 2017, 4), which accumulated in a depression between laterally projecting outcrops of the bedrock (Figure 1.7). This underlying geology consists of a flagstone and sandstone group of Middle Old Red Sandstone (Andrews and Trewin 2014, 414-415; Davidson and Jones 1985, 10). Sediments overlying the bedrock include glacial till, which is a common feature of Orcadian bays (Davidson et al. 1979, 10), silt and peat (Timpany 2017, 4).

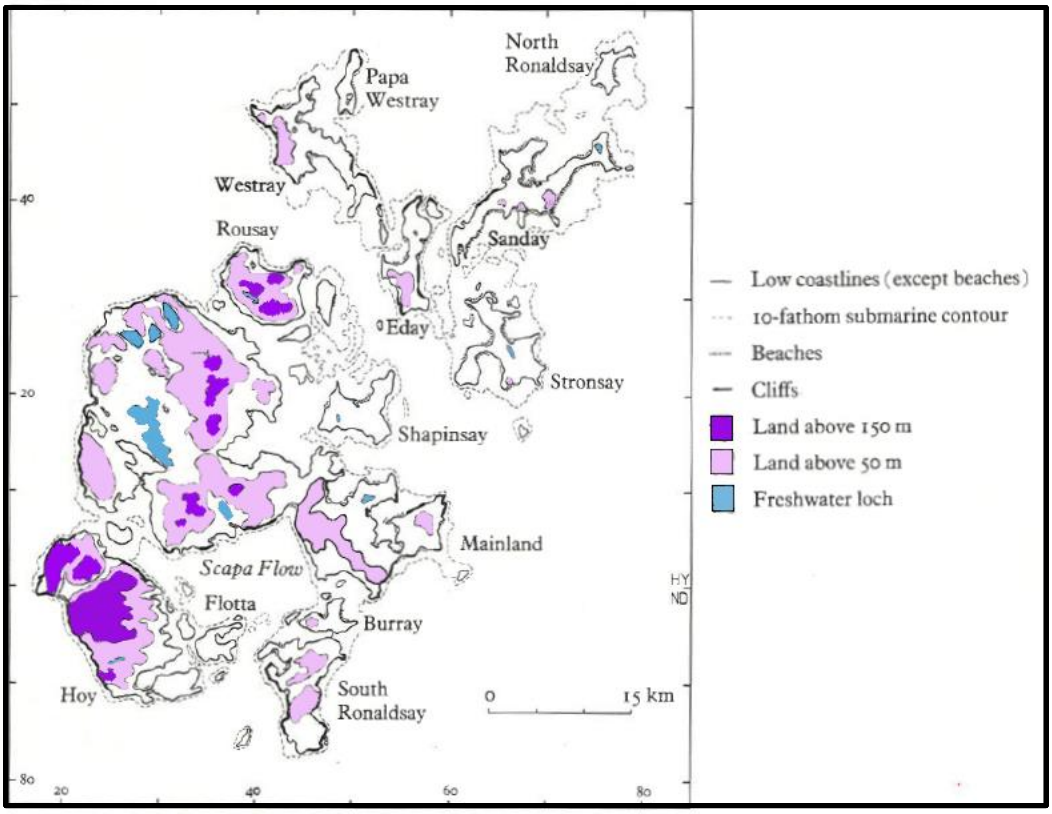


Figure 1.5: Topographic map of the Orkney Isles (after Davidson and Jones 1985, 14).

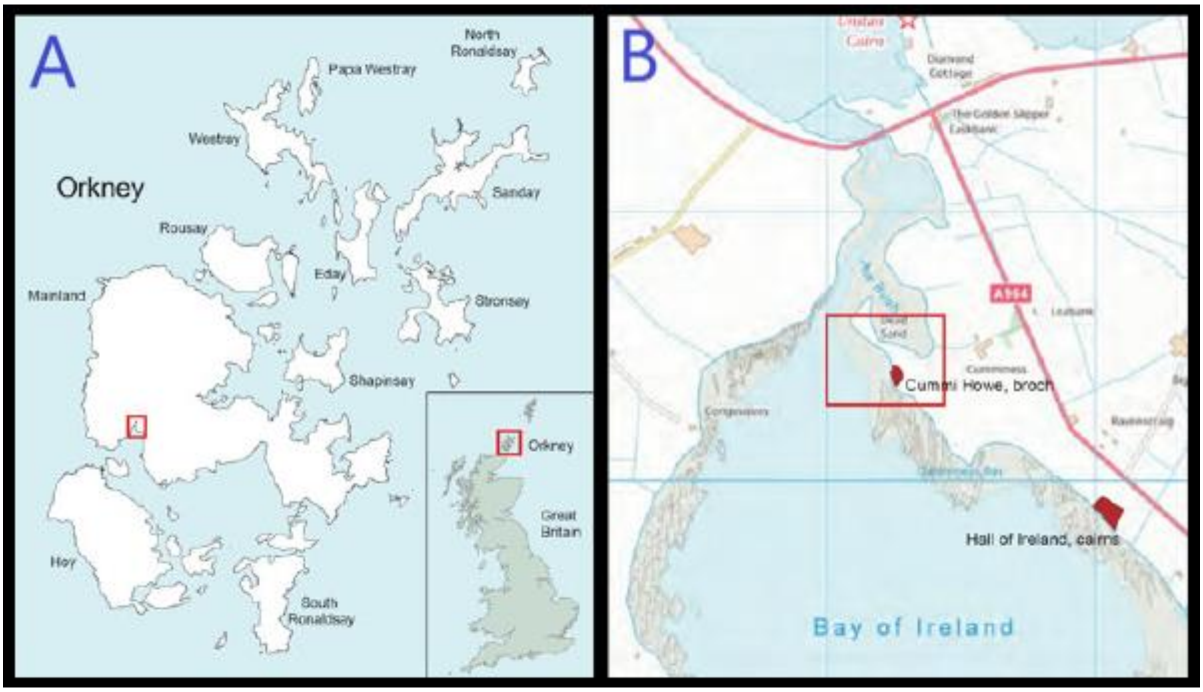


Figure 1.6: Bay of Ireland geographic site map. A- The location of the Bay of Ireland on Mainland Orkney; B- The position of the study site at the head of the Bay of Ireland (after Timpany et al. 2017, 3).

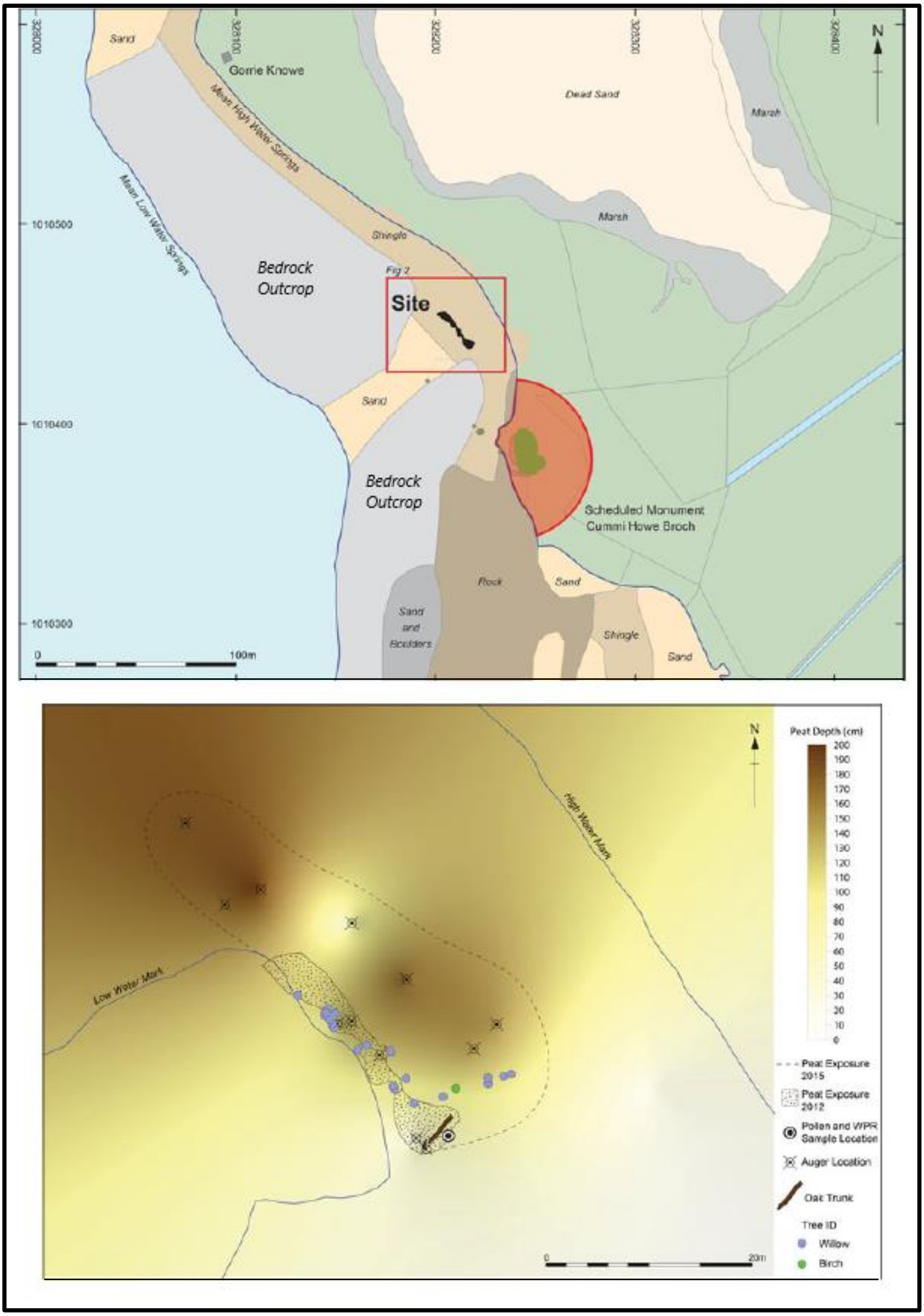


Figure 1.7: Bay of Ireland detailed site map. Top: Location of the site within the landscape; Bottom: Location of gouge auger transect, submerged forest remains, and oak plank (after Timpany et al. 2017, 3-4).

The Orcadian landscape consists of a treeless environment. Its modern vegetation includes only shrubs and herbaceous taxa. Though a formal survey of the local vegetation around the site was not undertaken, some observations regarding plant taxa in the immediate area were made on a visit to the site in mid-May. It features marginal vegetation made up of grasses, hydrophytes, and some coastal, salt tolerant taxa (Figure 1.8). Noted plant species include, *Filipendula ulmaria* (meadowsweet), *Cochlearia officinalis* (common scurvygrass), *Plantago maritima* (sea plantain), *Hydrocotyle vulgaris* (common pennywort), *Honckenya peploides* (sea sandwort), *Glaux maritima* (sea milkweed). Marine fungi (sea weed) were also present due to the intertidal nature of the site.

The discovery of the oak plank was of particular interest due to its potential anthropogenic origin. While there are no markings on the plank, it is believed to be a radial-split log connected to Mesolithic activities on the island (Figure 1.9) (Timpany et al. 2017, 5). Explanations for its deposition within the peat include intentional softening of the wood for working purposes and placement as a marker point (Timpany et al. 2017, 20). The former explanation has merit since the Bay of Ireland site is situated in an archaeologically active area of the landscape. The Cummi Howe Broch (an Iron Age structure) and the Hall of Ireland (a possible prehistoric cairn) lay along its shores (Timpany et al. 2017, 4), while the channel connecting the

Figure 1.8: Image of the oak plank in situ (Sharpe 2013, 9).

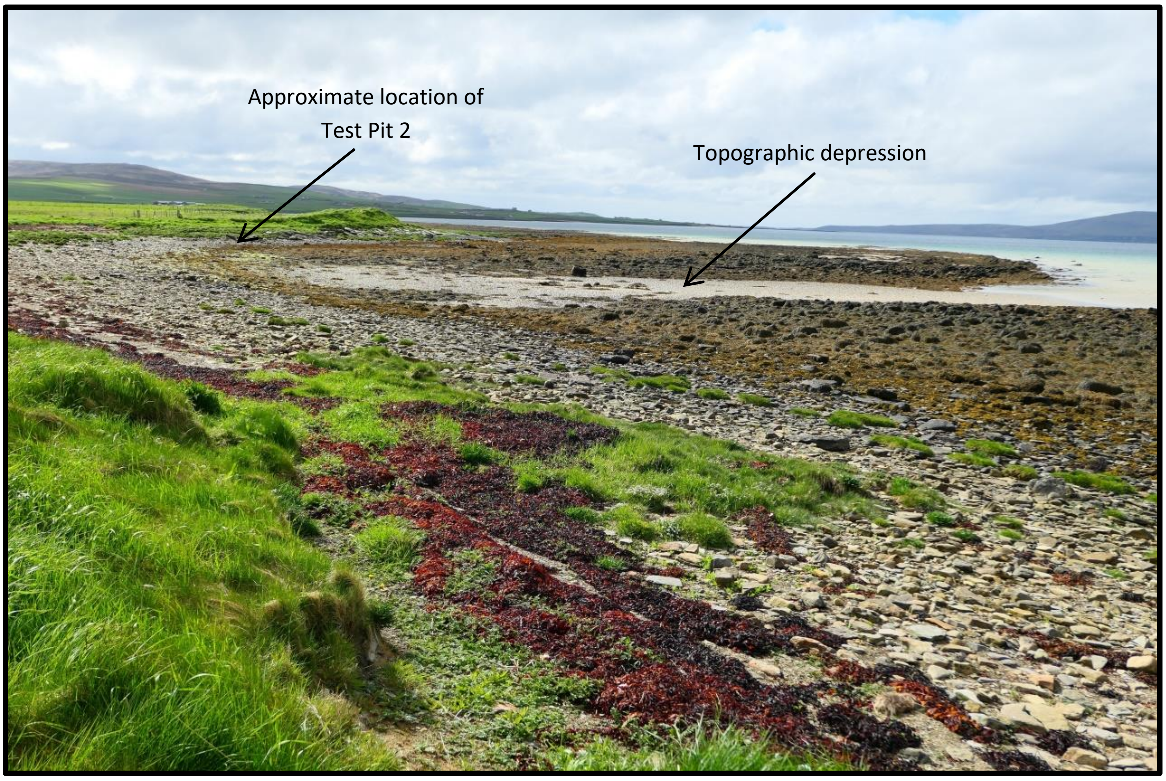


Figure 1.9: Image of the study site and its modern vegetation (Photograph by Dr. M.H. Field).

bay to the Loch of Stenness provides access to a rich area of archaeological remains, including Mesolithic flint scatters and Neolithic stone monuments (see Chapter 2 for details of Orkney's Archaeology).

The possibility that the Oak plank comprises part of a local prehistoric timber led to further investigations of the site (Timpany et al. 2017, 2). A trench was dug into the peat in order to determine its stratigraphic context before removal (Timpany et al. 2017, 5). Wood analysis provided a late Mesolithic felling date of 4410-4325 BC for the Oak plank and the layers of peat returned a radiocarbon date of c. 4690-4519 BC to c.4465-4356 BC (Timpany et al. 2017, 6 & 10). These results confirmed that both the timber and the time of its deposition date to the late Mesolithic period. Palaeoenvironmental samples were also collected from an additional trench (Test pit 1) dug next to the plank in order to investigate Orkney's prehistoric environment at this time (Timpany et al. 2017, 5). Samples were analysed for pollen, plant macrofossils and non-pollen palynomorphs. The results identified a wetland environment, which was interpreted as a reedswamp with open pools of water fringed by encroaching tree taxa (Timpany et al. 2017, 13). The environmental proxies also indicated the presence of grazing animals and Mesolithic management of the wetland through the use of fire (Timpany et al. 2017, 16-17). Thus, archaeological remains and palaeoenvironmental analyses suggest that anthropogenic activity occurred in and around the study site since the Mesolithic period.

Chapter 2: Early Prehistoric Orkney in Context

This chapter presents an overview of the current understanding of early Orcadian Prehistory. It discusses both archaeological remains from excavations and results from palaeoenvironmental investigations. The prehistory of Orkney technically extends from the Late Upper Palaeolithic (c. 13,000 – 9,000 BC) down to the end of the Pictish period (c. 800 AD) (Farrell 2009, 22). This chapter, however, only reviews what this thesis terms 'early prehistory,' which includes the Late Upper Palaeolithic, the Mesolithic and the Neolithic periods. Later periods of Orcadian prehistory are not included here, since the focus of this thesis research pertains solely to earlier prehistoric periods. The chapter concludes with a brief review of academic thinking regarding prehistoric human-plant interactions.

For Orkney, the visible and the invisible played a significant role in shaping initial thoughts regarding the islands' prehistory. Much has been made about the well-preserved remains of the Neolithic period. These stone structures served as obvious visual proof of a rich prehistoric past. The opposite is true for Orkney's environment. The current lack, or invisibility, of trees on the islands today provided an explanation for the dominance of prehistoric stone architecture and created the notion of woodland absence in Orcadian prehistory (Farrell et al. 2015, 225).

More recent archaeological and palaeoenvironmental investigations are now providing a higher resolution understanding of prehistoric Orkney beyond what can and cannot be seen. Over the past decade, a number of archaeological excavations have begun to uncover Mesolithic remains on the islands, while palaeoenvironmental analyses have been reassessing older interpretations of vegetation evidence, proving the notion of a treeless prehistoric environment to be a misconception. Consequently, Orcadian prehistoric investigations now aim to determine exactly when permanent habitation of the islands began, what the environment look like at this time, and how the early inhabitants may have affected this prehistoric landscape.

2.1 ARCHAEOLOGY

The impressive and highly visible remains of the Orcadian Neolithic have captivated the interest of archaeologists for centuries and caused this prehistoric period to become the focus of the majority of archaeological investigations on Orkney (Farrell et al. 2014, 225; Farrell 2015, 468). As a result, the Neolithic seems almost isolated in Orkney's prehistory, as if the inhabitants from this time period suddenly appeared without precursor. Research over the past decade, however, is changing that perception and demonstrating that Orkney's prehistoric past is much more complex. In addition to proof of Mesolithic occupation, there is also evidence for a development in early Neolithic building construction. Thus, the Neolithic does not stand alone in Orkney's history, but features as part of a longer period of prehistoric habitation which gradually evolved to the point of monumental stone architecture.

2.1.1 Late Upper Palaeolithic (c. 13,000-9,000 BC)

Evidence for Palaeolithic human presence in Scotland is scarce, comprising only a handful of questionable flaked stone tools, some of which derive from Orkney (Saville 2000, 91; Woodward 2007, 2). Upon their review, however, most of these finds became subject to question concerning Palaeolithic typology and/or Scottish origin (Saville 2000, 91-92). The only artefact that could not be completely dismissed comprised a tanged flint point recovered as a surface find from the island of Stronsay, Orkney. Since this stone tool has unfortunately been lost (Woodward 2007, 2), its analytical review depended on the examination of a 1950's illustration, which did not permit a clear determination of its typological period of origin (Saville 2000, 92). An archaeological survey of the island of Stronsay, Orkney in 2007, however, recovered an assemblage of flint stone tools in which two tanged flint points of 'Terminal Palaeolithic' type were confidently identified (Figure 2.1)

Figure 2.1: Surface lithic assemblage recovered during Stronsay, Orkney survey. The two top artefacts have been identified as Terminal Palaeolithic tanged points (Woodward 2007, 2).

(Woodward 2007, 2). These lithic artefacts now comprise the earliest evidence for a human presence in Scotland after the Last Ice Age.

2.1.2 Mesolithic (c. 9,000-4,000 BC)

The degree of Mesolithic presence on Orkney has been a highly speculative subject over the years (Saville 2000, 93). Archaeologists assumed that Mesolithic hunter-gathers at least visited the islands on foraging expeditions, since it is visible from mainland Scotland and offers access to excellent marine resources (Ritchie 1985, 36-37; Dawson et al. 2009, 3). Indeed, the recovery of Mesolithic flint microliths from the islands corroborated this assumption. These microliths, however, were few in number and most comprised isolated surface finds, lacking both dates and context (Saville 2000, 95). As such, they did not reveal whether Mesolithic people briefly visited the islands in passing or stayed for a longer period of time; they simply attested to anthropogenic activity on Orkney during the Mesolithic period.

The problem with recovering Mesolithic remains on Orkney pertains to visibility. This problem is two-fold. First, evidence of Mesolithic activity is often recovered from coastal areas (Dawson et al. 2009, 3; Mellars 2004, 171-172) and Orkney's coastlines have risen significantly since prehistoric times. Recent research estimates that c. 10,000 years ago Orcadian relative sea-levels were up to 45m lower than they are today (Dawson et al. 2009, 3). Hence, Mesolithic sites likely exist, but have been submerged by the sea and are no longer visible (Bates and Nayling 2013, 26; Dawson et al. 2009, 3; Wickham-Jones 2004, www.orkneyjar.com). Second, Mesolithic archaeological remains have likely been overlooked in the past, since they are generally less visible than remains from later periods (Wickham-Jones 2004, www.orkneyjar.com). As mobile hunter-gatherers who lived off the land's resources, Mesolithic people did not leave behind monumental structures (Wickham-Jones 2004, www.orkneyjar.com). Evidence of their settlements often includes only lithic flakes and debris from fires (Wickham-Jones 2004, www.orkneyjar.com). In contrast, Neolithic remains on Orkney comprise highly visible, well-preserved stone structures and archaeological interest has focused primarily on these finds.

As more recent Orcadian archaeological endeavours aim to investigate prehistoric periods other than the Neolithic, a clearer picture of Orkney's Mesolithic period is starting to emerge. A re-evaluation of flint assemblages from museum collections confirmed a definite Mesolithic presence on Orkney, characterized by some unique flaked tools (Saville 2000, 95). Additionally, field surveys and excavations are also producing new Mesolithic discoveries, increasing the number of identified Mesolithic sites on the islands (Figure 2.2 & Table 1.2). For example, the excavation of a Bronze Age barrow at Long Howe, Mainland Orkney produced stratified Mesolithic microliths. These flint finds came from the barrow's sediment matrix, as well as from sealed bedrock hollows beneath it (Wickham-Jones and Downes 2007, 147). One of the hollows also contained a charred hazelnut shell which returned a radiocarbon date of c. 6,820-6,660 BC (Wickham-Jones and

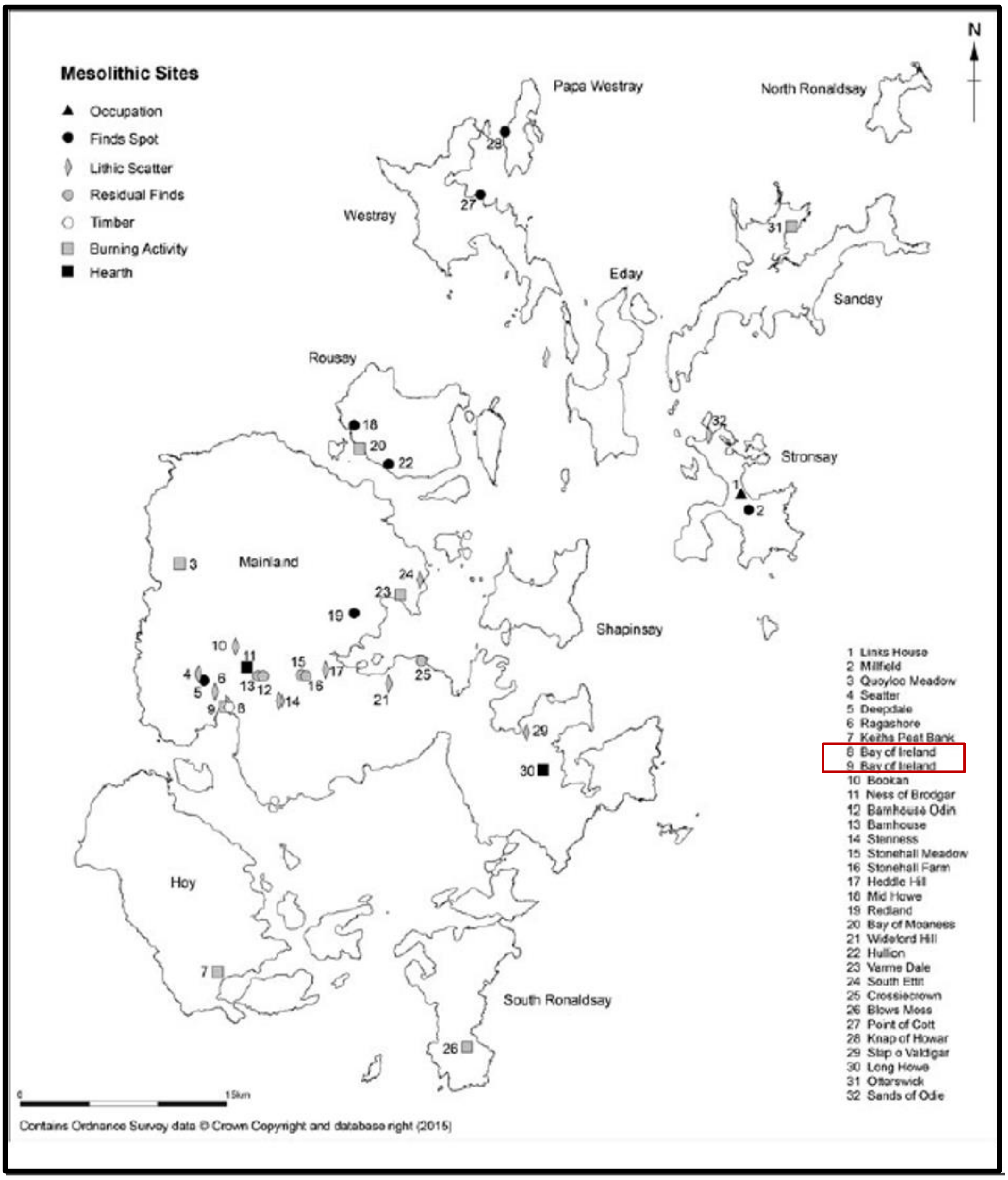


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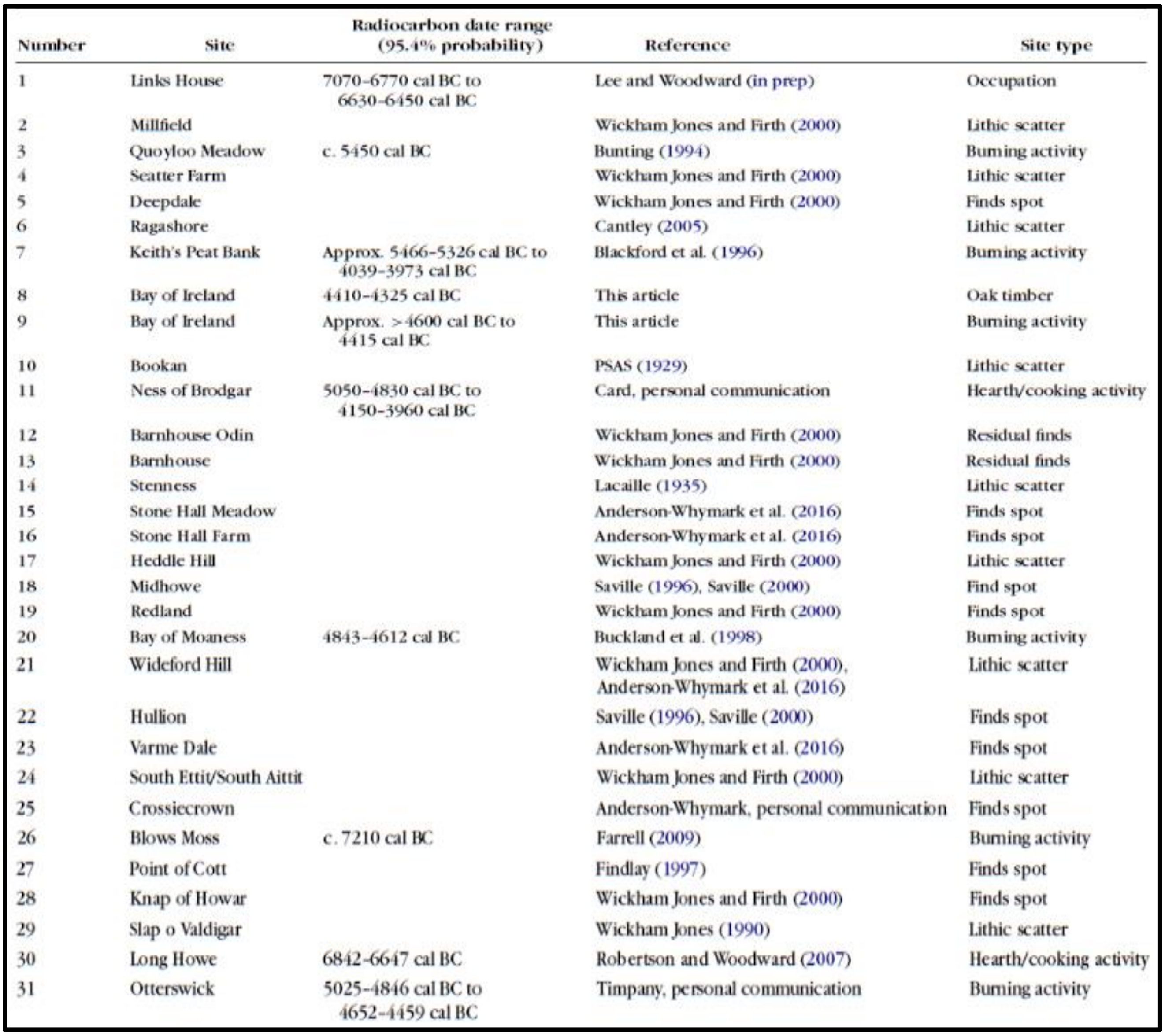
Figure 2.2: Map of Mesolithic sites on Orkney (Timpany et al. 2017, 16).

Table 2.1: Mesolithic sites on Orkney and their details (Timpany et al. 2017, 18-19).



Number	Site	Radiocarbon date range (95.4% probability)	Reference	Site type
1	Links House	7070–6770 cal BC to 6630–6450 cal BC	Lee and Woodward (in prep)	Occupation
2	Millfield		Wickham Jones and Firth (2000)	Lithic scatter
3	Quoyloo Meadow	c. 5450 cal BC	Bunting (1994)	Burning activity
4	Seatter Farm		Wickham Jones and Firth (2000)	Lithic scatter
5	Deepdale		Wickham Jones and Firth (2000)	Finds spot
6	Ragashore		Cantley (2005)	Lithic scatter
7	Keith's Peat Bank	Approx. 5466–5326 cal BC to 4039–3973 cal BC	Blackford et al. (1996)	Burning activity
8	Bay of Ireland	4410–4325 cal BC	This article	Oak timber
9	Bay of Ireland	Approx. >4600 cal BC to 4415 cal BC	This article	Burning activity
10	Bookan		PSAS (1929)	Lithic scatter
11	Ness of Brodgar	5050–4830 cal BC to 4150–3960 cal BC	Card, personal communication	Hearth/cooking activity
12	Barnhouse Odin		Wickham Jones and Firth (2000)	Residual finds
13	Barnhouse		Wickham Jones and Firth (2000)	Residual finds
14	Stenness		Lacaille (1935)	Lithic scatter
15	Stone Hall Meadow		Anderson-Whymark et al. (2016)	Finds spot
16	Stone Hall Farm		Anderson-Whymark et al. (2016)	Finds spot
17	Heddle Hill		Wickham Jones and Firth (2000)	Lithic scatter
18	Midhowe		Saville (1996), Saville (2000)	Find spot
19	Redland		Wickham Jones and Firth (2000)	Finds spot
20	Bay of Moaness	4843–4612 cal BC	Buckland et al. (1998)	Burning activity
21	Wideford Hill		Wickham Jones and Firth (2000), Anderson-Whymark et al. (2016)	Lithic scatter
22	Hullion		Saville (1996), Saville (2000)	Finds spot
23	Varme Dale		Anderson-Whymark et al. (2016)	Finds spot
24	South Ettit/South Aittit		Wickham Jones and Firth (2000)	Lithic scatter
25	Crossiecrown		Anderson-Whymark, personal communication	Finds spot
26	Blows Moss	c. 7210 cal BC	Farrell (2009)	Burning activity
27	Point of Cott		Findlay (1997)	Finds spot
28	Knap of Howar		Wickham Jones and Firth (2000)	Finds spot
29	Slap o Valdigar		Wickham Jones (1990)	Lithic scatter
30	Long Howe	6842-6647 cal BC	Robertson and Woodward (2007)	Hearth/cooking activity
31	Otterswick	5025–4846 cal BC to 4652–4459 cal BC	Timpany, personal communication	Burning activity

Downes 2007, 147). These finds provided the first contextually dated evidence for Mesolithic presence on Orkney (Wickham-Jones and Downes 2007, 147). Unfortunately, the microliths and the hazelnut shell still did not establish the nature of this Mesolithic presence. They only confirmed that Mesolithic people travelled to the islands, but did not indicate whether these travellers comprised temporary visitors or became permanent inhabitants.

Remains discovered during excavations on the island of Stronsay, on the other hand, appear to resolve this issue. This archaeological investigation – prompted by the survey recovery of Palaeolithic tanged points – has revealed flint scatters and postholes estimated to date to the Mesolithic period (Farrell 2009, 26).

These postholes, which would have facilitated timber-built structures, indicate a more prolonged Mesolithic presence – one which may have been permanent or semi-permanent in nature. Either way, the evidence clearly confirms that Mesolithic people did not just wander the islands during a foraging expiation, but inhabited them to some degree.

2.1.3 Neolithic (c. 4,000-2,000 BC)

Orkney is undoubtedly most famous for its Neolithic stone structures. This fame derives both from the wealth of structural remains surviving from this period and their incredibly well-preserved nature. In fact, for this very reason Neolithic Orkney has been called "one of the wonders of the prehistoric world" (Renfrew 2000, 1). The stone structures dating to this period demonstrate the construction of a whole range of building types, including domestic settlements, mortuary architecture and ritual monuments. While serving different functions, all of these structures display a sophisticated sense of architectural construction that would have required a substantial investment of manual labour.

Neolithic settlement on Orkney involved two types of domestic dwellings: farmsteads and villages. As the terms imply, farmsteads are characterized by one or two structures situated on their own, while villages comprise a cluster of houses all linked together by passageways. Both types of settlements often share some common construction features. For example, the early Neolithic farmstead at Knap of Howar (Figure 2.3) and the later Neolithic villages of Skara Brae (Figure 2.4), Rinyo and Links of Notland are all set into various kinds of mounds, creating a purposeful semi-subterranean nature to the structures (Ritchie 1985, 42; Clarke and Sharples 1985, 58-60). The sunken aspect of these settlements has been interpreted as a means of protection against the harsh Orcadian weather (Ottaway and Holton-Krayenbuhl 2009, 11). Structures of both settlement types also include stone-built domestic elements, such as recessed wall cupboards, dressers, box-like beds, drainage systems (Ritchie 1985, 45; Clark and Sharples 1985, 60-64; Ottaway and Holton-Krayenbuhl 2009, 31), emphasizing the inhabitants' mastery of stone construction. While stone forms the primary building material for the dwellings, Neolithic builders also incorporate some wooden elements, such as timber posts, timber roof rafters and bark lining for drains (Clarke and Sharples 1985, 64; Ritchie 1985, 38 & 44).

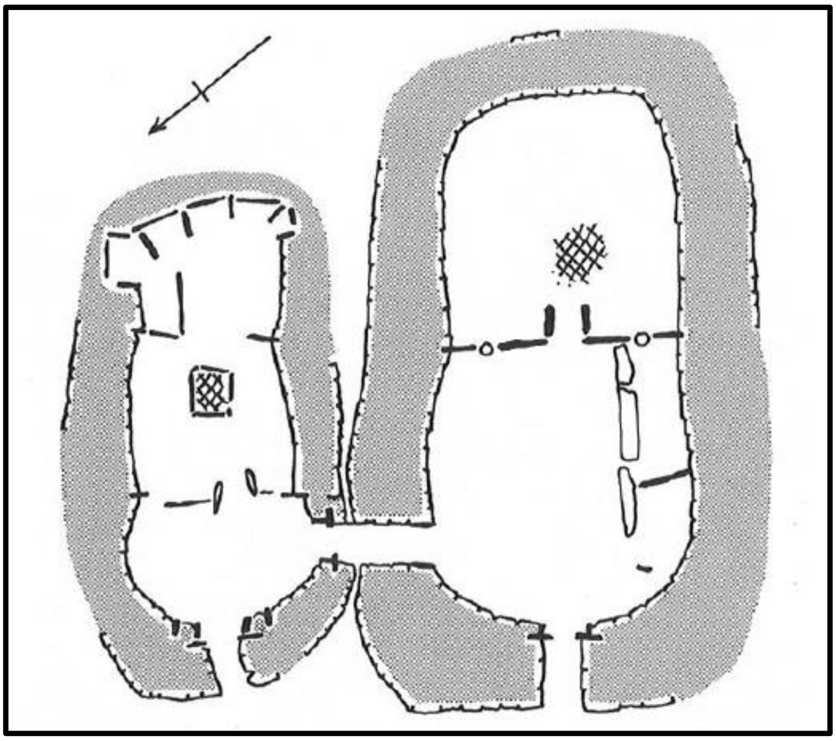


Figure 2.3: Plan of the Knap of Howar farmstead on Papa Westray, Orkney (Ritchie 1985, 43).

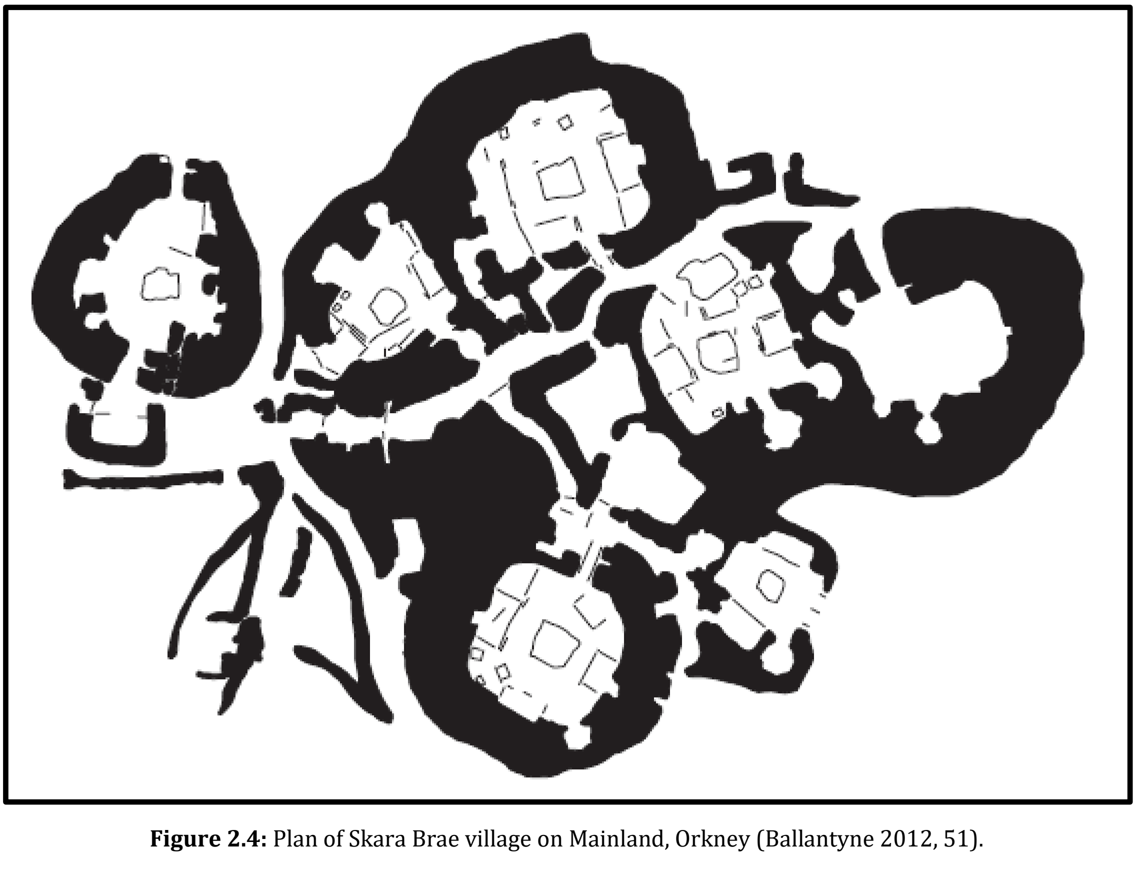


Figure 2.4: Plan of Skara Brae village on Mainland, Orkney (Ballantyne 2012, 51).

These remarkable Neolithic stone structures demonstrate such architectural sophistication and investment of labour that Anna Ritchie (1985, 39) believed they represented "products of a confident farming society, not the homes of the first pioneering colonists." The discovery of Mesolithic habitation evidence lends credence to Ritchie's assessment, proving that the Neolithic people responsible for building these structures do not constitute the first settlers of Orkney. In fact, more recent archaeological evidence from Wideford Hill further attests to the accuracy of Ritchie's statement. This site suggests that an earlier phase of Neolithic settlement existed before the construction of stone built structures.

The Wideford Hill excavations comprise the remains of three timber-built structures. These buildings were identified as the primary occupational phase of the site, which dates to as early as c. 3,620 BC (Richards and Jones 2016, 27). Evidence for the three structures constitutes scoop hearths and postholes outlining the original building configurations (Richards and Jones 2016, 21). Two of the structures demonstrate a circular house construction with relatively centralized hearths, while the third building comprises a more irregular shape, but still features a centralized hearth (Figure 2.5). The reason for the amorphous shape of the third and largest structure is not well understood. It may reflect later building additions to an originally circular structure, or the building may represent a different structure type altogether (Richards and Jones 2016, 21 & 26-27).

These newly excavated structures attest to the use of wood construction prior to the advent of stone architecture on Orkney. Some of the posthole sizes – up to 50cm in diameter from Structure 1 – indicate the use of fairly substantial timbers (Richards and Jones 2016, 23). Charcoal remains from the postholes imply the use of *Betula* (birch) for the structural timbers, while other charcoal remains from within the buildings suggest the additional use of *Salix* (willow), *Corylus* (hazel) and *Calluna* (heather) for additional construction purposes (Richards and Jones 2016, 23). The latter charcoal evidence could, however, also reflect fuel sources for the hearths. Some of the postholes from Structure 3 likely comprise storage pits, as they contained quantities of charred cereal grains (Richards and Jones 2016, 30). One such "pit/posthole" yielded a large cache of nearly 6,000 grains (Richards and Jones 2016, 30), attesting to the agricultural subsistence practiced by the inhabitants of these structures.

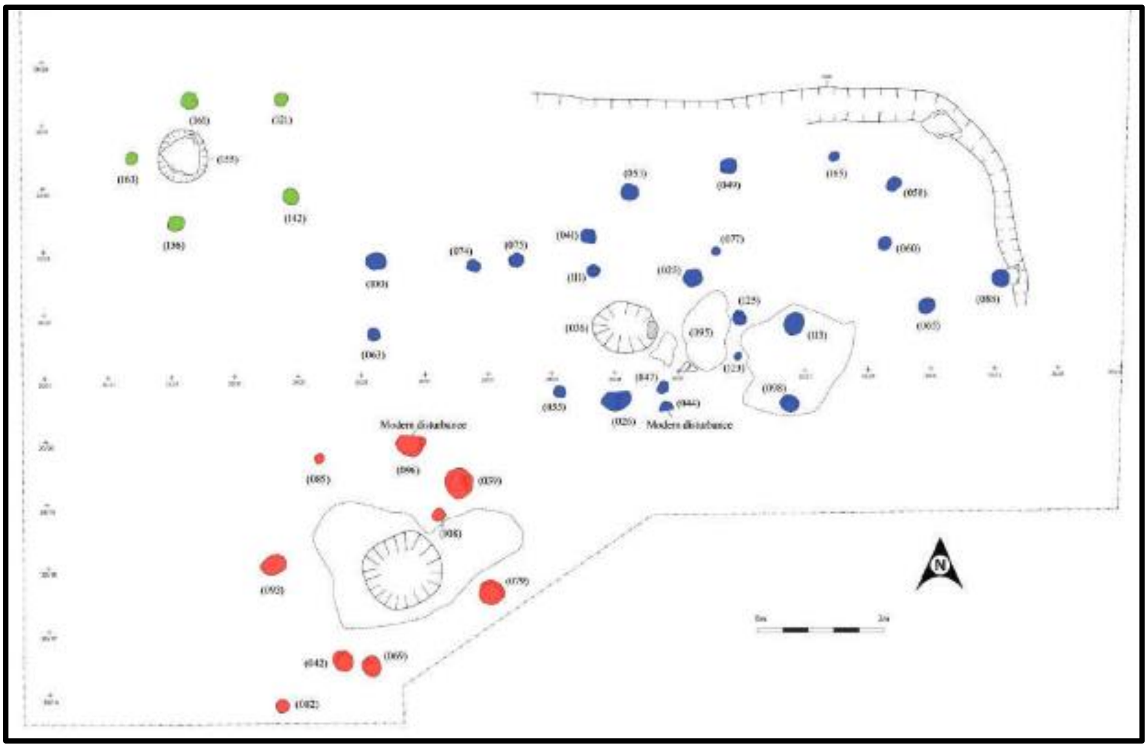


Figure 2.5: Plan of early Neolithic structures from Wideford Hill on Stronsay, Orkney. Red: Postholes for timber structure 1; Green: Postholes for timber structure 2; Blue: Postholes for timber structure 3. (Richards and Jones 2016, 21).

Due to the transient nature of timber dwellings, it is unclear whether these structures were built contemporaneously or not (Richards and Jones 2016, 38). Two of the buildings, however, demonstrate the inhabitants' evolution in architectural construction; for, these structures were later replaced by stone buildings. The conclusion that this construction activity occurred by the same inhabitants derives from evidence for immediate rebuilding. Firstly, timber structure 2 was overlain by a stone-built dwelling which incorporated the same centralized hearth into its building plan (Richards and Jones 2016, 26). Unlike foundations, or walls, the reuse of a hearth does not present any substantial benefit to later builders. The reuse of the hearth, therefore, suggests that the same occupants decided to preserve this feature during rebuilding. Secondly, some of the postholes from both timber structures 2 and 3 were discovered as voids during excavation (Figure 2.6), indicating that the end of their timber posts were still present when covered over by rebuilding activity and only rotted away later (Richards and Jones 2016, 25-30). This evidence suggests immediate rebuilding by the same inhabitants, since a time-lag did not occur between the destruction of the timber dwellings and the construction of the stone buildings (Richards and Jones 2016, 30). Thus, Wideford

Hill provides unique evidence for the transition from timber construction to stone architecture by early Neolithic Orcadian inhabitants (Farrell et al. 2014, 226).

Figure 2.6: Posthole 'void' from timber structure 2 (Richards and Jones 2016, 25).

Neolithic stone architecture on Orkney also includes chambered tombs and ritual monuments. The chambered tombs, known as cairns, share several architectural similarities with settlement dwellings (Ritchie 1985, 50). These tombs comprise single stone-built chambers set into mounds which are accessed via long passageways. Like domestic structures, the cairns are represented by two types. The first type comprises chambers with compartments created by upright flagstones, while the second type consists of chambers with recessed cells (Ottaway and Holton-Krayenbulh 2009, 11). Skeletal evidence indicates that both types of cairns were used as communal tombs, housing the remains of numerous individuals. The Ibister cairn, also known as 'The Tomb of the Eagles' was in use from c. 3,000-2,500 BC and contained the remains of 342 separate burials (Ottaway 2009, 41-42). The common architectural features found in both domestic dwellings and the tombs have prompted suggestions that the cairns were "built as houses for the dead, emulating the house of the living" (Ritchie 1985, 52).

The similarities between the two kinds of structures, however, may simply reflect practical stone architectural techniques. In fact, some of the chamber tombs, such as Maes Howe c. 2,750 BC, exhibit architectural features not incorporated in the construction of stone dwellings – the most conspicuous being corbelled vaulting and celestial alignment (Ottaway 2009, 55). The inclusion of these elements in the construction of the chamber tomb likely reflects the nature of the building. As a ritualistic, communal building, this cairn was likely meant to inspire a sense of awe and wonder, both from a structural and a religious standpoint. In this vein, the chambered cairns also appear to share qualities with the ritual stone monuments of the Neolithic period. Orkney features two monumental stone henges, both located in proximity to each other on the western Mainland. The Stones of Stenness dates to c. 3,100 and the Ring of Brodgar was constructed sometime between c. 2,500-2,000 BC. While both stone circles display the same architectural design, they differ in construction scale. The Stones of Stenness comprised 12 stone monoliths erected in a 30 metre diameter circle, while the Ring of Brodgar consisted of roughly 60 monolith stones erected in 104 meter diameter circle (Ottaway 2009, 42-44).

Thus, Orcadian prehistoric building construction demonstrates a clear progression from simple timber dwellings to complex stone architecture. In fact, the timber structures at Wideford Hill are not an isolated incident. Excavations at Braes of Ha'Breck on the island of Wyre also discovered the remains of early Neolithic timber-built structures (Thomas 2016, 34). Like at Wideford Hill, these timber structures were purposefully replaced by stone buildings (Farrell et al. 2015, 232). This evidence makes Anne Ritchie's comment, regarding the village of Skara Brae, appear incredibly perceptive. For, communities did settle the Orkney Isles prior to the Neolithic inhabitants that built sophisticated stone structures. These early settlers exploited the local woodland for their building purposes and only switched to stone construction later on. As Richards and Jones (2016, 16) state, this early occupation simply represents "a less archaeologically visible period of settlement" during Orkney's prehistory.

2.2 PALAEOENVIRONMENTAL INVESTIGATIONS

This thesis research uncovered 15 published investigations that examine Orkney's early prehistoric environment. These investigations derive from 22 different sites from both Mainland Orkney and from some of the other Orcadian islands. They vary in terms of their early prehistoric coverage – some examining only a single period, while others examine a much longer sequence – as well as the methodological approaches they employ in order to conduct their research. The majority of earlier investigations relied heavily on pollen analysis as the basis for their palaeoenvironmental reconstructions, while studies from the last decade adopt a more comprehensive, multidisciplinary approach.

2.2.1 Late Upper Palaeolithic (c. 13,000-9,000 BC)

Only two Orcadian palaeoenvironmental sites have provided stratigraphic sequences deep enough to investigate the Late Upper Palaeolithic environment. These sites comprise Crudale Meadow and Quoyloo Meadow on the western Mainland. Over the past 45 years, three separate palaeoenvironmental investigations have been conducted at Crudale Meadow (Bunting 1994; Moar 1969; Whittington et al. 2015). While Bunting (1994) and Moar (1969) concentrate purely on reconstructing the vegetational environment at this time, Whittington et al. (2015) use the vegetational evidence as part of a wider, multidisciplinary reconstruction of Orkney's palaeoclimate. Bunting (1994) is the only researcher to have also investigated the Late Upper Palaeolithic sequence from Quoyloo Meadow.

Unfortunately, the palaeoenvironmental analyses from these sites do not offer high chronological resolution, since both Crudale Meadow and Quoyloo Meadow suffer from hard water effect (Bunting 1994, 775; Whittington et al. 2015, 123). Robust dating was therefore not possible and the sequences are dated biostratigraphically (Bunting 1994; Moar 1969) or lithostratigraphically (Whittington et al. 2015) using an identified tephra layer (Farrell 2014, 225). Nevertheless, all four investigations provided similar conclusions regarding Orkney's early post-glacial vegetation. They determined that Orkney comprised an open landscape during this period, containing a mix of grassland and heathland (Moar 1969, 207). Late Upper Palaeolithic Orkney thus consisted of a tundra environment (Whittington et al. 2015, 123), supporting "dwarf-shrub heath" and "artic-alpine" species (Bunting 1994, 775).

2.2.2 Mesolithic (c. 9,000-4,000 BC)

The Mesolithic is a well-investigated period for the palaeoenvironment of early prehistoric Orkney. Out of the total 22 published analyses, 15 sediment sequences span the Mesolithic period (Figure 2.7). Some of these analyses resorted to biostratigraphical dating techniques when hard water effect contaminated the carbon content of their samples (Table 2.2). Almost half of the total investigations, however, have been radiocarbon dated, providing secure dates for local vegetation changes. While most of these investigations focus on different research agendas, such as Orcadian vegetation history (Moar 1969; Bunting 1994), the development of machair (de la Vega-Leinert et al 2000) or the initiation of blanket peat (Bunting

1996) they all inevitably discuss the highly debated presence of a Mesolithic woodland on Orkney.

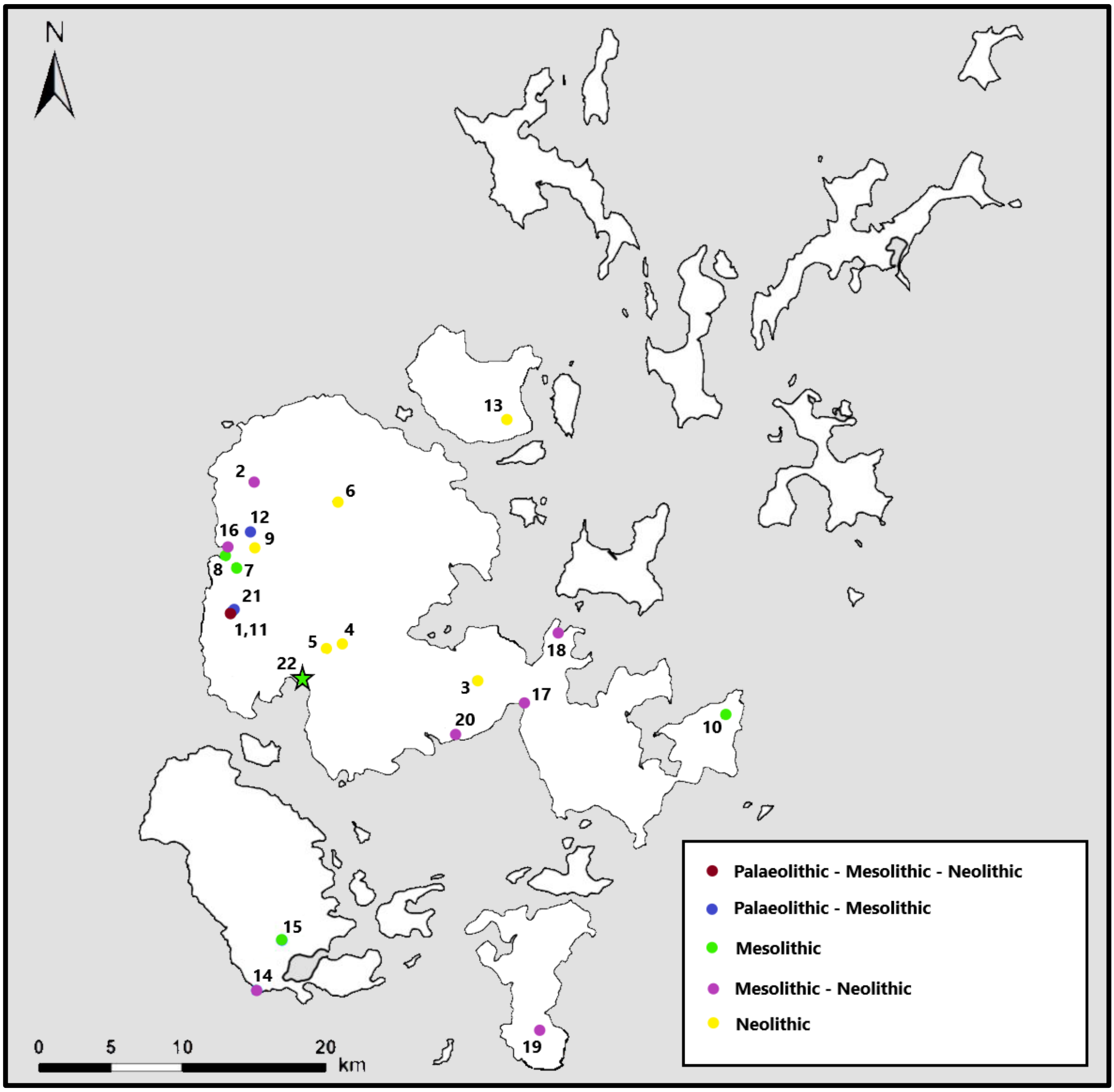


Figure 2.7: Map of early prehistoric palaeoenvironmental investigations of Orkney (after Farrell 2009, 112). Star indicates Bay of Ireland; see Table 2.2 for the corresponding list of sites.

Table 2.2: Early prehistoric palaeoenvironmental investigations of Orkney.

#	Article	Year	Site	Analysis Type	Sequence period	Means of Dating
1	Moar	1969	Yesnaby (Crudale Meadow)	pollen	Palaeolithic-Mesolithic-Neolithic	biostratigraphy
2			The Loons	pollen	Mesolithic-Neolithic	biostratigraphy
3	Davidson et al.	1976	Lesliedale Moss	pollen	Late Neo	radiocarbon
4			Maes Howe	pollen	Late Neo	radiocarbon
5	Castledine and Whittington	1976	Stones of Stenness	pollen	Neolithic	radiocarbon
6	Keatinge & Dickson	1979	Glim Moss	pollen	Neolithic	radiocarbon
7			Loch of Skaill	pollen (considers some macros)	Mesolithic-Neolithic	hard water effect
8			Bay of Skaill	pollen	Neolithic	biostratigraphy
9			Pow	pollen	Neolithic	biostratigraphy
10	Donaldson	1986	Brough of Deerness (Stove)	pollen	Mesolithic	(unreliable - likely contaminated)
11	Bunting	1994	Crudale Meadow	pollen and macros	Palaeolithic, Mesolithic, Neolithic	hard water effect = biostratigraphy
12			Quoyloo Meadow	pollen and macros	Palaeolithic, Mesolithic, Neolithic	hard water effect = biostratigraphy
13	Bunting	1996	Loch of Knitchen (Rousay)	pollen	Neolithic	radiocarbon
14			Loch of Torness (Hoy)	pollen	Mesolithic-Neolithic	radiocarbon
15	Blackford	1996	Keith's Peat Bank (Hoy)	pollen	Mesolithic	radiocarbon
16	de la Vega-Leinert et al.	2000	Bay of Skaill	pollen, molluscs, ostracods	Late Mesolithic-Neolithic	hard water effect
17	de la Vega-Leinert et al.	2007	Scapa Bay	pollen, diatoms	Mesolithic-Neolithic	radiocarbon
18	de la Vega-Leinert et al.	2012	Bay of Carness	pollen, macros and diatoms	Late Meso-Neolithic	radiocarbon
19	Farrell et al.	2014	Blows Moss (Ronaldsay)	pollen	Mesolithic-Neolithic	radiocarbon
20	Farrell	2015	Hobbister (site A)	pollen, NPPs	Late Meso-Neolithic	radiocarbon
21	Whittington et al.	2015	Crudale Meadow	pollen, stable isotopes, molluscs	Palaeolithic, Mesolithic	hard water effect = lithostratigraphy
22	Timpany et al.	2017	Bay of Ireland	pollen, NPPs, macros	Mesolithic	radiocarbon

Similar to Orcadian archaeology, Mesolithic palaeoenvironmental research for Orkney has followed a line of progression. Early investigations give the impression of being influenced by Orkney's visible, modern flora. In Moar's (1969, 206) investigation of past Orcadian vegetation, he concentrates on comparing his prehistoric pollen results against the modern Orcadian flora. In order to explain high values for tree taxa on a currently treeless island, Moar collected surface samples to investigate the possibility of long distance pollen transport from the Scottish mainland (Moar 1969, 203 & 206). Obtaining positive results, he then disregarded values of *Pinus*, *Quercus* (oak)*, Alnus* (alder)*,* and *Ulmus* (elm) pollen from his sequences (Moar 1968, 207). Interestingly, along with high values of *Pinus* pollen, the surface samples also recorded high values of *Betula* pollen. Moar (1969, 207), however, did not disregard the *Betula*, nor *Corylus,* evidence from his sequence, since these trees have long been established as native components of Orkney's palaeoenvironment due to the frequent recovery of their fossils (Bunting 1994, 784; Moar). Despite prior accounts of extensive submerged forest remains on Orkney (Traill 1868; Watt 1820 – see chapter 5 for more details), Moar (1969, 208) concludes that "the Orkney islands were never more than barren in aspect and at best, scrubland of birch and hazel predominated during the middle period of the Flandrian."

While Moar (1969) bases his interpretations on scientific evidence, his conclusions were no doubt partly influenced by Orkney's current treeless environment. For, the results of his surface sample investigation did not negate the possibility of a Mesolithic woodland presence on Orkney, but simply confirmed that *Pinus* pollen is rather susceptible to long distance transport via the wind. If anything, his results demonstrate the inherent taphonomic issue associated with the palynological investigations of tree taxa. Nevertheless, subsequent palaeoenvironmental investigations of Orkney followed Moar' s (1969) lead and largely dismissed tree taxa other than *Betula* and *Corylus* from their analyses, claiming that Orkney's Mesolithic vegetation consisted primarily of a birch-hazel scrub (Donaldson 1986, 11; Keatinge and Dickson 1979, 591 & 604). While Donaldson (1986, 11-13) concluded that Betula and Corylus likely formed a more substantial woodland than mere 'scrub' or 'shrubland', it is Bunting (1994) that first acknowledges a true woodland presence for the Orcadian Mesolithic (Farrell et al. 2014, 226).

In Bunting's (1994) analysis of sediment sequences from Crudale and Quoyloo Meadow, which span from the Late Upper Palaeolithic period down to the Neolithic period, she encounters various woodland tree taxa pollen represented during the Mesolithic period. These taxa include *Betula*, *Corylus*, *Alnus*, *Quercus*, and *Pinus*, but, unlike previous palaeoenvironmental investigations of Mesolithic Orkney, Bunting does not dismiss this pollen evidence as the product of long distance transport. She actually accepts the possibility of their presence, based on proven instances for their existence at other Northern locations such as Scandinavia and Shetland (Bunting 1994, 784-785). She concludes that a mixed woodland – dominated by *Betula* and *Corylus*, but including *Alnus*, *Quercus*, and *Pinus* – developed during Orkney's early prehistory (Bunting 1994, 790). After her publication, other palaeoenvironmentalists also begin to accept recorded values of Orcadian tree taxa pollen during the Mesolithic. While certain studies still attribute *Pinus* and/or *Quercus* values to long distance transport and others equate them with a local presence (de la Vega-Leinert et al. 2000, 515; de la Vega-Leinert et al. 2007, 767; Farrell 2015, 479), *Alnus* and *Ulmus* values are generally acknowledge as contributing to Orkney's Mesolithic woodland.

Results from securely dated pollen analyses suggest that the Orcadian mixed woodland became established on the island from c. 7,400 cal BC (Bunting 1994, 787; De la Vega-Leinert et al. 2007, 766; Farrell 2014, 227-230) and reached is maximum c. 5,900 cal BC (Bunting 1994, 778; de la Vega-Leinert et al. 2007, 767). Some sites, such as Keith's Peat Bank, Quoyloo Meadow and Blows Moss, demonstrate temporary declines in tree pollen values during the later Mesolithic period, which is often attributed to anthropogenic disturbance of the woodland (Farrell et al. 2014, 230). This same disturbance was also observed at the Bay of Ireland and ascribed to Mesolithic burning of wetland vegetation (Timpany et al. 2017, 17). At other sites, the disturbance to tree pollen values is attributed to natural causes, such as changing hydrological conditions (Farrell 2014, 230-231) – a factor known to affect local vegetation (Farrell 2014, 231).

Thus, the Orcadian Mesolithic comprises a dynamic period for prehistoric vegetation. A visually impactful change from tundra-like conditions to semi-forested woodland transformed Orkney's landscape and no doubt rendered it more appealing to later Mesolithic communities. In addition to kilometres of maritime coastline, Orkney also possessed a wooded environment. The combination of resources offered by these landscape features – maritime and forest subsistence, construction material, and a fuel source – made the islands attractive for Mesolithic habitation (Donalson 1986, 12-13). As the archaeological and palaeoenvironmental records show, people did indeed settle in Orkney during the Mesolithic period and utilized its local vegetative resources.

2.2.3 Neolithic (c. 4,000-2,000 BC)

There is a long-held notion that Orkney's first settlers arrived during the Neolithic period to a treeless environment which led them to build stone structures (Farrell et al. 2015, 225). Both recent archaeological excavations and palaeoenvironmental investigations have proved this notion to be false (Farrell et al. 2014, 234). Settlers arrived in the Orkney Isles prior to the Neolithic and encountered a partially wooded environment upon their arrival. After the Mesolithic disruption to local vegetation, woodland areas either recovered to their former extent or continued at a reduced level (Farrell 2014, 230-231). Either way, woodland survived the Mesolithic disturbance and continued into the Neolithic period. Palynological analysis reveals, however, that further vegetation changes in the Neolithic began to shape the islands' environment into its current floristic landscape (Bunting 1994, 771).

Unsurprisingly, the majority of the palaeoenvironmental investigations carried out in Orkney cover the Neolithic period. Most of these sediment sequences record a significant decline in Orcadian woodland pollen values at this point in the islands prehistory, with the exception of sequences that only begin in the later Neolithic (Davidson et al. 1976). Early investigations recognize this decline as decreasing values for 'birch-hazel scrub' or 'shrubland' (Keatinge and Dickson 1979; Moar 1968), since they ignore other tree taxa pollen values. Interestingly, however, their pollen diagrams demonstrate that even these disregarded values decrease alongside *Betula* and *Corylus*, effectively representing the woodland decline (Figure 2.8).

The long-standing narrative for woodland decline holds that trees were eradicated from the island during the first centuries of the Neolithic due to their agricultural activities (Farrell et al. 2014, 225 & 230-231). Indeed, increased settlement evidence and the characteristic farming practices of this prehistoric period no doubt impacted local vegetation. Large-scale woodland clearance, in the form of tree felling and burning, created vegetation regrowth for grazing animals and open landscapes for crop cultivation (Bunting 1994 778; Farrell et al. 2014, 231;

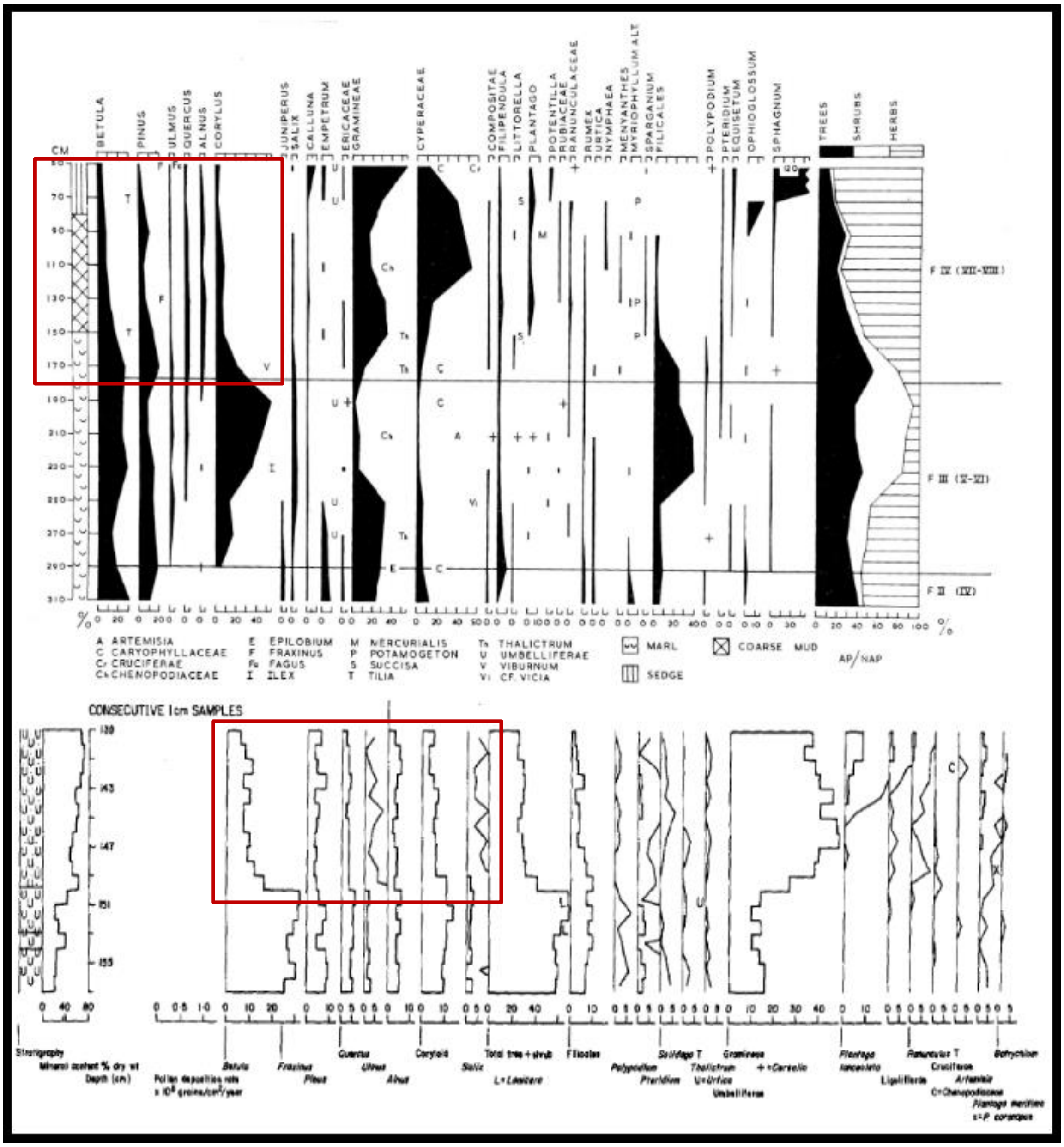


Figure 2.8: Pollen diagrams showing Neolithic decline of all tree taxa. Top: The Loons (Moar 1969, 205); Bottom: Loch of Skaill (Keatinge and Dickson 1979, 596).

de la Vega-Leinert et al. 2012, 137). Evidence for such activities comes from the appearance of synanthropic plant taxa, such as *Plantago lanceolata*, *Artemisia*, *Rumex*, and Chenopodiaceae, in conjunction with declining woodland taxa values (Bunting 1994, 777-778; Bunting 1996, 199; Farrell et al. 2014, 230; Farrell 2015, 476; Jones 1979, 21; Keatinge and Dickson 1979 588-590; Moar 1968, 207; de la Vega-Leinert et al. 2000, 520; de la Vega-Leinert et al. 2007, 767; de la Vega-Leinert et al. 2012, 137). These plants are often associated with farming practices, since they thrive on disturbed ground (Innes et al. 2013, 96). Additionally, increased microscopic charcoal serves as evidence for wide-scale woodland clearance associated with Neolithic farming practices (Bunting 1994, 777; Bunting 1996, 209; Farrell et al. 2014, 230; de la Vega-Leinert et al. 2007, 767). Very few researchers attribute woodland decline (Neolithic and/or Mesolithic) to causes other than anthropogenic activity (notable exceptions comprise: Bunting 1996, 211 – Loch of Torness; Farrell et al. 2014, 230 – Blows Moss)

Farrell et al (2014, 230-231), however, believe the notion of woodland decline solely due to anthropogenic activity during the early Neolithic to be false. They demonstrate that Orcadian woodland decline occurred at various times in various locations (Farrell et al. 2014, 231). At some sites, the decline occurred earlier, in the Mesolithic, while at other sites, woodland persisted into the later Bronze Age (Figure 2.9) (Farrell et al. 2014, 231-232). The lack of a synchronous decline leads these authors to state that a single regional cause does not fully explain the disappearance of the prehistoric Orcadian woodland (Farrell et al. 2014, 234). They feel that the eradication of trees on Orkney resulted from a more complex combination of both regional and local causal factors, which includes – but is not limited to – anthropogenic activity (Farrell et al. 2014, 231 & 234).

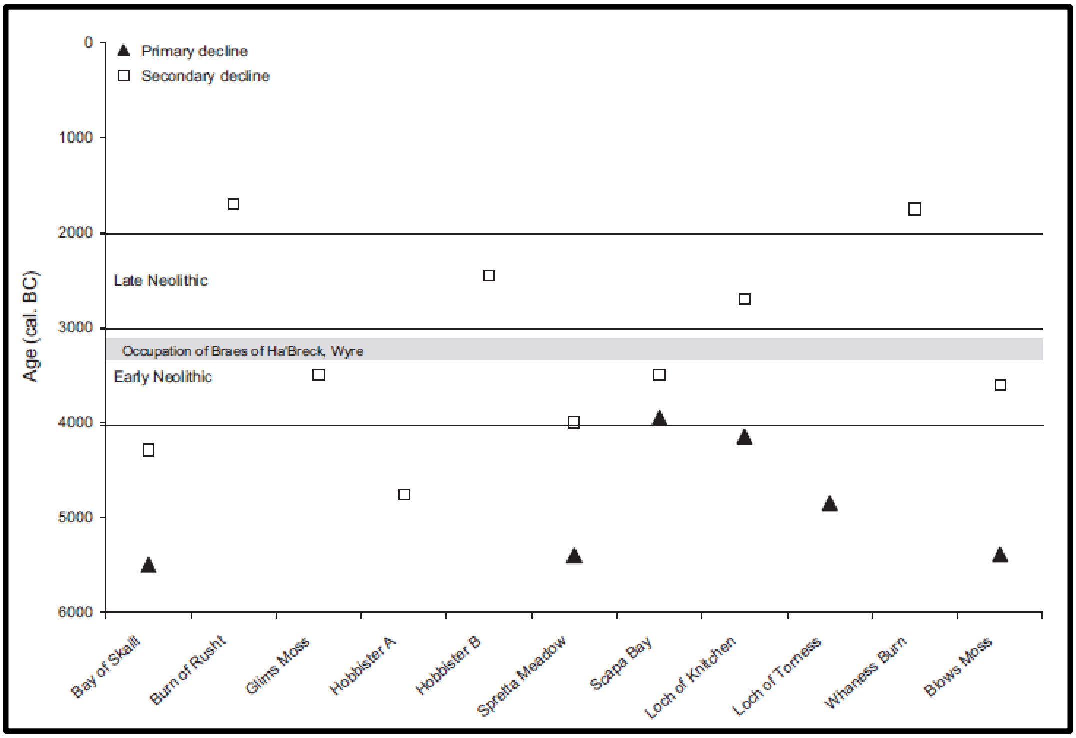


Figure 2.9: Timing of woodland decline at different sites. Includes published and unpublished sites (Farrell 2009), as well as later Bronze Age sequences not included in this thesis review (Farrell et al. 2014, 231).

2.3 HUMAN-PLANT INTERACTIONS

While the Mesolithic-Neolithic transition is characterized by increasing anthropogenic plant exploitation practices that culminated in the large-scale environmental impact of Neolithic agriculture, the degree to which earlier Mesolithic communities interacted with the surrounding plant-life is still highly debated among researchers (Bishop et al. 2015, 51).

Traditional notions of Mesolithic communities envisioned hunter-gatherers as subjects of the landscape. Godwin (1956) believed that the forest dominated Mesolithic man by dictating all aspects of his life (Smith 1970, 81). Iversen (1949) expressed a similar opinion, commenting that "primitive Mesolithic man was entirely dependent on nature," (Smith 1970, 81). These views emphasize the hunting-gathering aspect of these communities, implying that they were no more than passive beneficiaries of the surrounding landscape who subsisted off of the locally available flora and fauna until quantities were depleted or seasonal availability ended, forcing them to relocate. This concept of the Mesolithic way of life suggests that the communities of the period made no effort to cultivate resource supplies and thus, their activities did not greatly impact the environment (Bishop et al. 2105, 63).

In contrast, active manipulation and promotion of subsistence resource defines the subsequent Neolithic period. The innovation of animal husbandry and agriculture – characteristic features of the Neolithic lifestyle – had an enormous impact on local vegetation. Neolithic communities not only domesticate wild resources, but also altered the landscape in order to engage in these pursuits. They cleared large areas of woodland and disturbed large areas of ground for the planting of crops and the grazing of animals (Bishop et al. 2015, 52; Brown 1997, 136 & 142). These activities interrupted the natural environment, resulting in vegetational successions which permanently affected floristic ecologies. For example, reduction in woodland facilitated the growth of open ground and heliophytic plant species, while the increased ground disturbance allowed for the invasion of synanthropic weed taxa (Brown 1997, 134-135). In fact, taxa such as *Rumex*, *Chenopodium* and *Plantago lanceolata* occur so regularly in horizons associated with Neolithic agricultural practices that researchers have also begun to use their presence as indicators of earlier anthropogenic disruptions to vegetation (Innes et al. 2013, 96).

The difference between the passive Mesolithic lifestyle and the active Neolithic lifestyle seems a rather abrupt change in human-plant interactions. In 1970, Smith suggested that Mesolithic man may not have been as passive a component of the landscape as once thought. He posited that later Mesolithic communities may have intentionally or unintentionally impacted surrounding plant life through their use of fire to drive game (Smith 1970, 81-82). Smith (1970, 82-83) speculated that this activity may have led to the prehistoric observation that *Corylus* is largely fire resistant, causing Mesolithic man to use fire to promote its growth over other tree taxa in order to profit from its hazelnut production. In fact, the recovery of 30,000-40,000 carbonized hazelnuts from Staosnaig F24 provides a prime example of intensive Mesolithic exploitation of this tree taxa, which may have result from just such a cultivation method (Bishop et al. 2015, 63).While Smith's view regarding Mesolithic *Corylus* cultivation has met with scepticism (Bishop et al. 2015, 67), his suggestion that Mesolithic communities impacted vegetation through the use of fire found resonance with later palaeoenvironmental research.

Over the past few decades, palynological studies have often observed temporary woodland recessions occurring during the Mesolithic period (Edwards and Whittington 2003, 67-70; Farrell et al. 2014, 231). These recessions often consist of temporary disruptions to tree taxa values in pollen diagrams accompanied by microscopic charcoal remains (Bishop et al. 2015, 66). After a period of woodland decline, most pollen diagrams indicate a recovery of tree values (Edwards and Whittington 2003, 67-70; Farrell et al. 2014, 230). Palynologists often interpret such woodland disturbances as the management of vegetation by Mesolithic communities (Innes et al. 2013, 81). In addition to driving game, researchers now believe that Mesolithic man also used fire as a means to attract game, by encouraging the new shoot growth of plants (Innes et al. 2013, 81; Tinsley 1975, 17; Tipping 1994, 17) and creating/maintaining woodland clearings (Brown 1997, 138; Innes et al. 2013, 94). Thus, prehistoric studies now view Mesolithic man as a semi-active agent of the landscape who interacted with the surrounding vegetation, as opposed to a passive bystander who simply benefited from the natural flora.

While it seems reasonable that later Mesolithic communities began to assert some measure of control over their environment, especially in connection with promoting woodland resources, the interpretation of Mesolithic plant management is most credible when accompanied by the full spectrum of evidence for human activity. This evidence includes microscopic charcoal remains, synanthropic plants and archaeological artefacts, in addition to decreased tree taxa values. Some researchers, however, readily attribute Mesolithic tree taxa declines to human activity when only one or two of these lines of evidence are present. In such instances, anthropogenic responsibility for woodland disturbance remains equivocal and other causal factors could be equally responsible. In fact, several authors note that early-mid Holocene fluctuations in tree taxa abundance can also result from a number of autogenic or climatically driven factors (Brown 1997, 141; Tipping 1994, 14; Woodbridge et al. 2014, 217). Thus, Brown (1997, 133-134 & 142) warns against anthropocentric explanations to vegetation disruptions and successions, since they tend to “minimise” ecological and environmental causes for change. Farrell et al. (2014) have recently called attention the occurrence of this trend among previous Orcadian palaeoenvironment investigations and the erroneous narrative it has created regarding prehistoric human-plant interactions on Orkney.

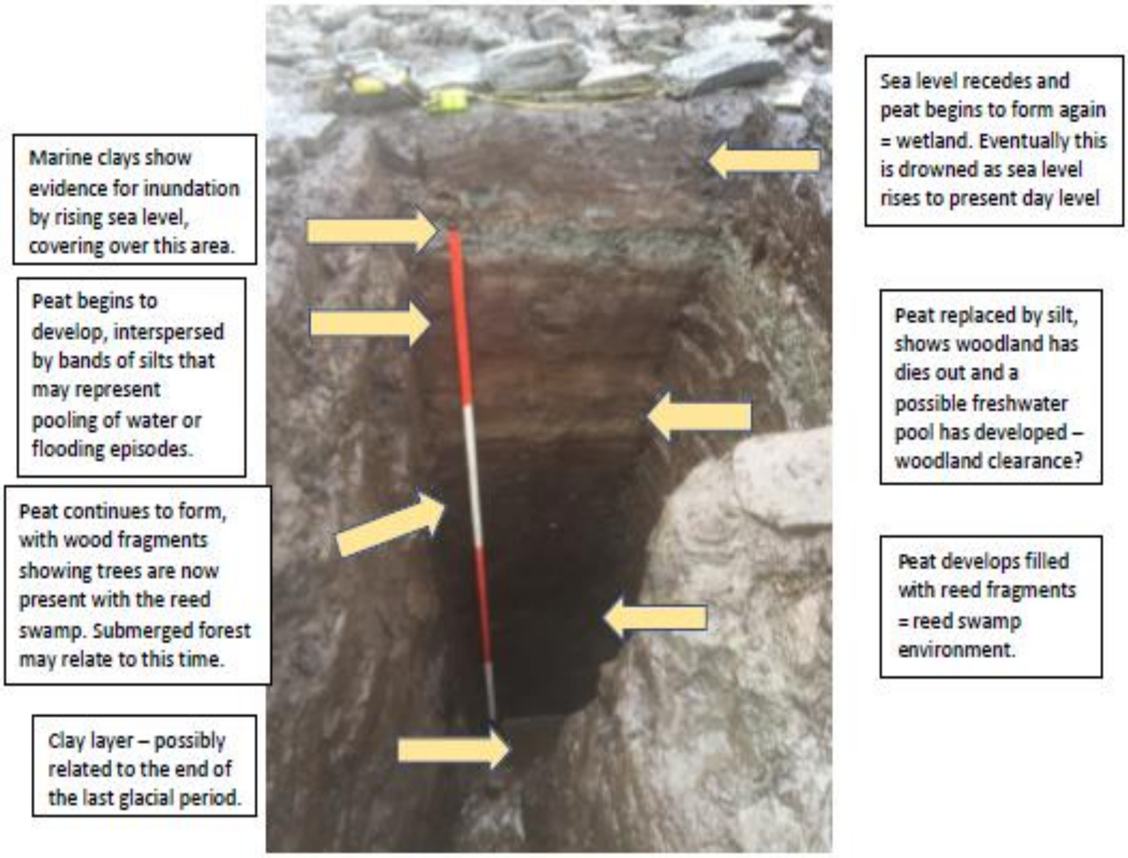
Chapter 3: Methodology

This chapter presents the methods used throughout the research investigation. It describes fieldwork and radiocarbon sampling which occurred prior to the commencement of this study. It also outlines criteria considered for sample selection, the procedures followed during sample analysis and the material components examined as palaeoenvironmental proxies.

3.1 FIELDWORK

As a continuation of the palaeoenvironmental investigation into Orkney's prehistoric environment at the Bay of Ireland site, an additional test pit (Test Pit 2), independent of the oak plank, was dug further to the northeast – in the area of the foreshore. This test pit measured 3m long x 1m wide x 2 m deep and revealed peat accumulation up to a depth of ca. 2m (Buhat 2018, 12 & 28). Preliminary, on-site examination of the highly-visible stratigraphy indicated several phases of landscape change involving a similar wetland environment as detected in Test pit 1 (Figure 3.1) (Buhat 2018, 13). This stratigraphic sequence, however, escaped the coastal erosion which truncated the peat layers of Test Pit 1and provided a longer temporal record extending beyond the Mesolithic into more recent prehistoric periods. Monolith samples measuring 50 cm in length, 20cm in width and 10cm in depth were taken contiguously, stretching the length of the stratigraphic sequence of the pit, for palaeoenvironmental analysis.

In addition to the monoliths, samples were also collected from stratigraphic horizons for a palaeoentomological investigation of Orkney's prehistoric environment. This study comprised the analysis of coleoptera (beetle) remains and was carried out before the present research was undertaken (Buhat 2018). The results of this previous study are discussed in Chapter 5 as part of a wider discourse concerning the research findings produced by the current macrofossil work and those produced from other palaeoenvironmental proxies.



Marine clays show evidence for inundation by rising sea level, covering over this area.

Peat begins to develop, interspersed by bands of silts that may represent pooling of water or flooding episodes.

Peat continues to form, with wood fragments showing trees are now present with the reed swamp. Submerged forest may relate to this time.

Clay layer – possibly related to the end of the last glacial period.

Sea level recedes and peat begins to form again = wetland. Eventually this is drowned as sea level rises to present day level

Peat replaced by silt, shows woodland has dies out and a possible freshwater pool has developed – woodland clearance?

Peat develops filled with reed fragments = reed swamp environment.

Figure 3.1: Visible stratigraphy of Test Pit 2 (Buhat 2018, 13).

3.2 RADIOCARBON DATES

Prior to the commencement of sample analysis, radiocarbon dates had already been obtained for the monolith stratigraphy, as well as the submerged forest remains. Samples from tree stumps 10 and 28 (both *Salix*) returned dates of 3804–3694 cal BC and 3806–3698 cal BC respectively (Timpany et al. 2017, 7), indicating that the submerged trees consist of early Neolithic woodland remains. Seven points corresponding to observable environmental changes throughout the monolith sequence were also dated using Accelerate Mass Spectrometry (AMS) at the Scottish Universities Environmental Research Center (SUERC) (Buhat 2018, 31). To ensure the accuracy of the results, both the humic and humin content were dated separately for each of the stratigraphic locations, providing a total of 14 radiocarbon dates (Buhat 2018, 31). The results demonstrate that the temporal record of the monolith sequence stretches from the late Mesolithic to the early Iron Age. Figure 3.2 presents both a description of the various stratigraphic layers and the results of the radiocarbon dates. For more detailed information regarding the radiocarbon sampling and results, see Appendices 1 & 2.

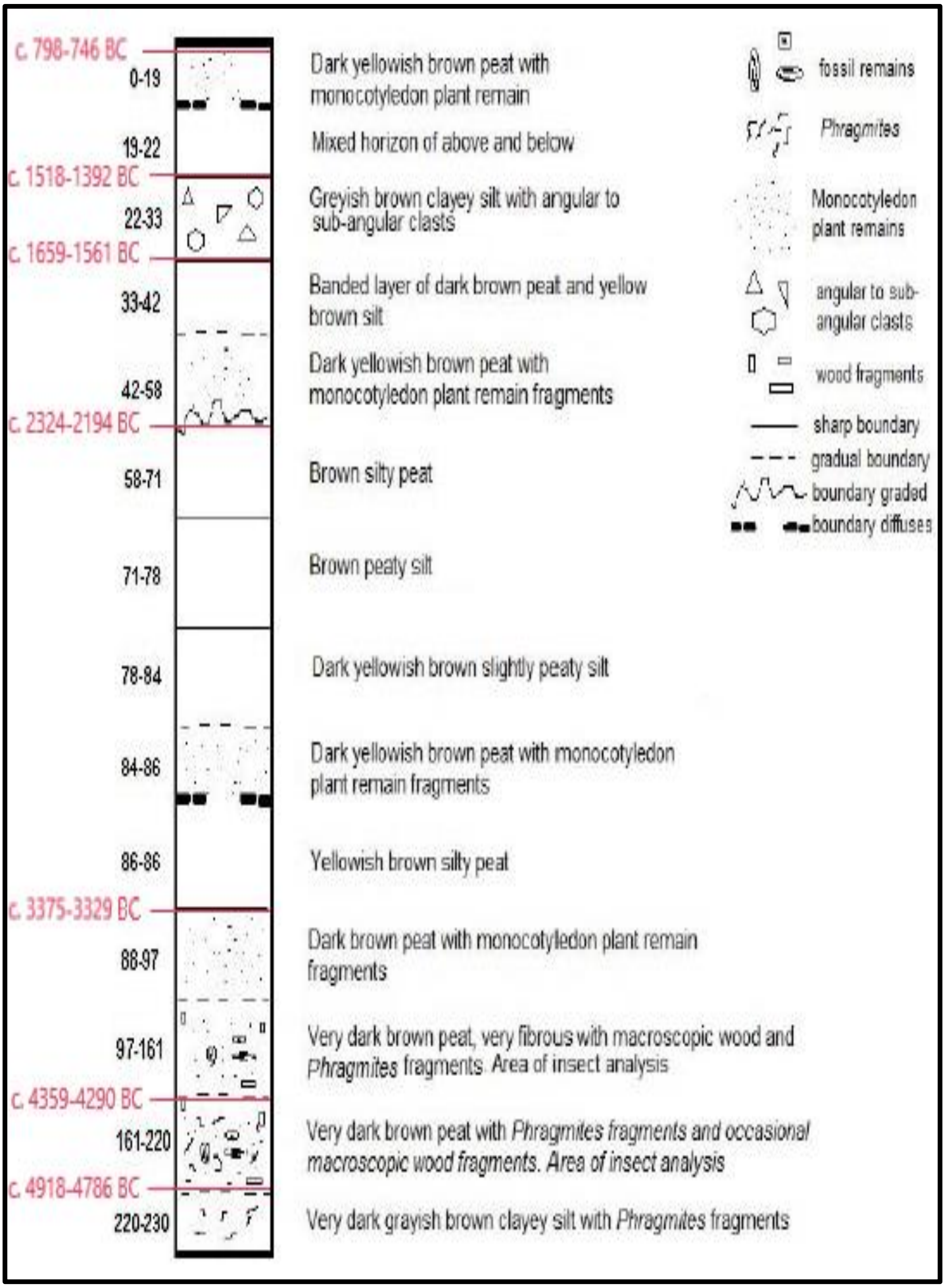


Figure 3.2: Stratigraphic interpretation and radiocarbon dates for Test Pit 2 sequence (after Buhat 2018, 30).

3.3 SAMPLE SELECTION AND PROCESSING

Five 2cm block samples were taken out of the monoliths from the bottom 120cms of the stratigraphic sequence by Dr. Scott Timpany at the University of the Highlands and Islands Orkney College (Orkney College UHI) in Scotland. Dr. Timpany specifically chose this section of the stratigraphy for analysis since its horizons coincide with those of the before-mentioned palaeoentomological study of Orkney's prehistoric environment (Buhat 2018). The five samples correspond to radiocarbon dates spanning the late Mesolithic to early Neolithic periods and were sent to Leiden University via courier for processing. Two of the samples came from unit II of the test pit's stratigraphic sequence, while the other three samples came from unit III. These horizons consisted of reed peat (unit II) and wood peat (unit III) interpreted from the Bay of Ireland pollen diagram as representing a changing vegetational environment with an increasing local presence of tree taxa (see Appendix 3 for the Test pit's full stratigraphic interpretation).

Due to time constraints, only three of the five samples were selected for the palaeoenvironmental investigation covered by this thesis research: one sample from each end of the temporal range and one from the middle. Sample 1 consisted of sediment deposition from 188-186 cm, Sample 2 comprised sediment deposition from 144-142 cm, and Sample 3 represented sediment deposition from 104-102 cm. These samples offered confident date estimations for the investigation due to their close proximity to radiocarbon sample points. Table 3.1 presents date estimations for all the samples based on mid-point calculations made from the known radiocarbon dates and further mid-point extrapolations. Thus, the sample selection ensured an even temporal analysis of the past vegetation, covering a transitional timeframe from one prehistoric period to another.

Each of the three samples was subsampled to 100 cm^3. Sample volume was measured by adding sediment to 300ml of water until the water was displaced to 400ml. The samples were then poured into buckets, with extra water added, and left to disaggregate for a week. Periodic agitation of the samples encouraged disaggregation. After samples appeared fully disaggregated, they were poured through a stack of four sieves in order to wash away all the sediment from the organic matter. The four sieve mesh sizes consisted of 1mm, 500 µm, 250 µm, and 150 µm. The very fine 150 µm mesh size was included in the stack of sieves to ensure the recovery of even the smallest plant remains, such as sporangia from ferns. The organic material was then collected from the sieves, maintaining the four fraction sizes, for analysis under a Leica stereomicroscope (S6E) with vertical lighting and low-powered 6-40x magnification. All plant macrofossil remains were extracted from the four fractions at 32x, 20x, 12.5x, and 8x magnification and kept in dishes with one-to-one alcohol hydroglycerin preservation solution.

Table 3.1: Date estimations for sample selection.

Depth (cm)	Sample Type	Date (BC)	Estimated Date (BC)	Corresponding Period
89	Radiocarbon	c. 3,329-3,375	c. 3,352	
104-102	**Sample 3**		**c. 3,596**	Early Neolithic
124-122	unselected sample		c. 3,839	
144-142	**Sample 2**		**c. 4,082**	Transition
161	Radiocarbon	c. 4,290-4,359	c. 4,325	
172-170	unselected sample		c. 4,457	
188-186	**Sample 1**		**c. 4,589**	Late Mesolithic
219	Radiocarbon	c. 4,786-4,918	c. 4,852	

3.4 PLANT MACROFOSSIL REMAINS

The identification of waterlogged seeds was made according to morphological characteristics. The level of taxonomic recognition depended on the condition of the remains, such as the state of preservation and degree of fragmentation, as well as the presence or absence of characteristic features that permit secure identifications. Consultation with a seed atlas (Cappers et al. 2009) aided with identifications down to genus-level, while comparison with Leiden University's archaeobotanical reference collection facilitated species-level identifications. In a single case of subspecies recognition, high-resolution photographs and morphological characteristics provided by Stace (1997) allowed for a confident identification.

In addition to the low-powered microscopic recognition of plant taxa, high-powered microscopic analysis was required for the species identification of *Juncus* seeds. After grouping these fossils based on similar typology, a seed from each type was split and mounted on a microscope slide for viewing under a high-powered Leica microscope (DM 750) at 100x and 400x magnification. Comparison with reference material allowed for an assessment of the overall size and shape of seeds, while consultation with identification keys compiled by Köber-Grohne (1964) facilitated a detailed study of cell pattern similarity and an evaluation of toothed projections. The extent of *Juncus* seed remains in the reference collection limited the number of possible species-level identifications to two taxa. The remaining type of *Juncus* seed was recorded as Type A, whose characteristics are described in full detail in Chapter 4. *Juncus* seeds degraded beyond the point of cell pattern recognition using low-powered microscopy were simply identified as *Juncus* sp.

After completion of the identification process, the number of individuals within each plant taxon were counted and recorded for each of the three samples in order to produce quantitative-based results beyond mere presence or absence of taxa. The identification and quantification of taxa enabled the discernment of temporal variations in the concentration of floristic communities, as well as changes in their ecological composition. Pieces of fossil taxa that did not confidently denote a single individual were recorded as fragments and also included in the counts, since their presence could potentially indicate important taphonomic processes relevant to the palaeoenvironmental interpretation. Upon completion of sample processing and analysis, all seeds were curated according to sample, using glass tubes filled with one-to-one alcohol hydroglycerin preservation solution, for future reference.

While waterlogged seeds comprised the main macrofossil plant remain used as a palaeoenvironmental proxy for this research, charcoal and wood remains were also considered. Wood remains can sometimes provide additional information regarding the presence of tree taxa that are underrepresented by seed macrofossils, such as *Salix*. Charcoal, on the other hand, can indicate potential disruption to the local vegetation, accounting for changes in vegetation composition. Thus, all wood and charcoal fragments encountered during sample processing were extracted and their numbers recorded. The wood remains for each sample were stored in labelled tubes filled with alcohol and shipped back to Dr. Timpany for thin-section analysis at Orkney College UHI. The charcoal remains, however, consisted of tiny fragments (<3mm in size) that did not merit further analysis. Unfortunately, the size and fragility of these fragments precluded their curation as part of the recovered macrofossil remains for each sample.

3.5 DATA PRESENTATION

Since the macrofossil analysis involved only three different samples, the generation of a concentration diagram, using software such as TILIA, seemed rather fruitless. It was determined that the comparisons and contrasts in taxa distribution through time would be just as readily apparent from quantitative data tables. Thus, all data table presentation derives from the use of Microsoft Excel.

Chapter 4: Results

The current chapter presents the plant macrofossil results (Table 4.1) from the three analysed sediment horizons from the Bay of Ireland site that serve as the waterlogged plant remain evidence for the extended palaeoenvironmental investigation of Orkney's prehistoric vegetation. Each sample is discussed chronologically in turn from the oldest (late Mesolithic) to youngest (early Neolithic), providing information for all fossil types recovered and identified during processing and analysis. Some notes on specific taxa identification are also given. Unfortunately, wood identifications were not made before the submission of this thesis, and thus remain absent from the results.

4.1 SAMPLE 1 (188-186CM): LATE MESOLITHIC

Plant macrofossils recovered from the basal zone indicate a wetland environment with some shallow pools and woodland fringe. Tall herbaceous taxa, such as *Schoenoplectus tabernaemontani* (soft-stemmed bulrush) (Figure 4.1 A), dominate the assemblage and denote local soil saturation. Several species of rushes from the Juncaceae family were also present, including *J. articulatus* (jointed-rush), as well as an unidentifiable monocotyledon (likely *Phragmites* given that the sample from this horizon comprised *Phragmites* peat) represented by the remains of internodal plates (Figure 4.1 B). Some sedges, *Carex sp*. and *Eleocharis sp.*, also contribute to the local tall-flora community. The presence of some shallow pooling of water in the area is ascertained from the occasional fruit remains of submerged aquatic taxa, deriving from the Potamogetonaceae (pondweed) and Ruppiaceae (tasselweed) families. *Ruppia maritima* (beaked tasselweed) (Figure 4.1 C) not only denote the occurrence of pools, but – as a halophyte – also indicate a degree of local soil salinization. The recovery of *Juncus gerardii* seeds, another halophytic taxa, further attests to this aspect of the local ecology.

Table 4.1: Plant Macrofossil Results.

Taxon	Fossil	Sample 1 (188-186cm)	Sample 2 (144-142cm)	Sample 3 (104-102cm)
Atriplex sp.	achene	2	8	
	achene fragments	2		
Betula sp.	fruits	44	14	9
	cf. fruits	5		
	catkin scales			1
Callitriche sp.				49
Carex dioica	nutlets with utricle			13
	nutlets without utricle			22
cf. Carex dioica	nutlets			14
Carex sp.	biconvex nutlets	2	3	
	trigonous nutlets	4	4	2
	nutlets	2		3
Cirsium sp.	seeds			1
Cochlearia officinalis	seeds		4	
	seed fragments		1	
	pod halves		2	
cf. Cochlearia sp.	seeds		6	
Potentilla palustre	seeds			10
	seed fragments			5
cf. Potentilla palustre	seeds			3
Eleocharis sp.	nutlets	1		2
Juncus articulatus	seeds	2	33	39
Juncus gerardii	seeds	2	40	
Juncus sp. Type A	seeds	2	26	366
Juncus sp.	seeds	4	114	595
Lychnis flos-cuculi	seeds	1	12	10
	seed fragments	4		
Lychnis cf. viscaria	seeds			1
Mentha cf. aquatica	seeds			9
Menyanthes trifoliata	seeds			2
	seed fragments			1
Moehringia trinerva	seeds	7	2	
Montia fontana ssp. fontana	seeds		4	
Potamogeton polygonifolius	fruits			27
Potamogeton sp.	fruits	1		
Ranunculus subg. ranunculus	fruits		1	
	fruit halves			4
Rumex sp.	achene	4	9	
	achene fragments	3		
Ruppia maritima	fruits	2		
cf. Sagina sp.	seeds	1	107	10
Schoenoplectus tabernaemontani	nutlets with perianth-bristles	32	1	
	nutlets without perianth-bristles	254	9	
	nutlet fragments	3	1	
Selaginella selaginoides	spore			1
Stellaria holostea	seeds		1	
Stellaria media	seeds			1
Urtica dioica	seeds	2		1
Viola sp.	seeds	1		
cf. Viola sp.	seed fragments		2	1
Musci				2
cf. Dryopteris	sporangia	66	51	
Monocotyledon	whole internodal plates	8		
	internodal plate fragments	9		
Indet	seeds	3	1	12
Tree-bud	scales	1		13
	whole buds			4
Wood		5	7	45
Charcoal		30	14	

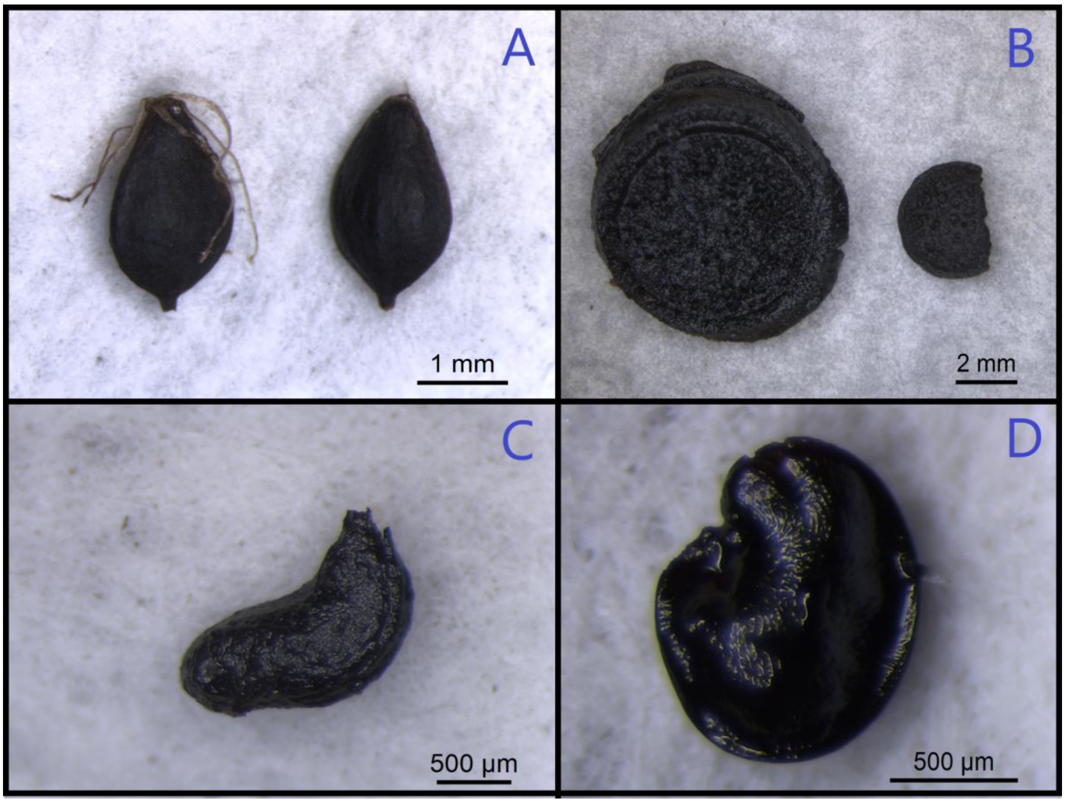


Figure 4.1: Some ecologically important fossil taxa recovered from Sample 1 (188-186cm): A-Nutlets of *Schoenoplectus tabernaemontani* with perianth-bristles (left) and without perianth-bristles (right); B- Internodal plates from a monocotyledon; C- The halophyte *Ruppia maritima*; D-*Moehringia trinerva* with visible tapered margin.

Other herbaceous taxa, such as *Lychnis flos-cuculi* (ragged-robin), cf. *Sagina sp.* (pearlworts), and sporangia from *Dryopteris*-type ferns also suggest damp surroundings. *Atriplex sp.* (oraches), *Rumex sp.* (docks), *Viola sp*. (violets), and *Urtica dioica* (common nettle) existed amongst this damp flora, though some these taxa may also reflect a slight disturbance to the local vegetation. *Urtica dioica* is commonly associated with animal dung, possibly indicating that the disturbance comprised the presence of grazing animals in the vicinity. Nearby woodland presence is indicated by the fossil fruits of *Betula sp*. (birch), the shady habitat preference of *Moehringia trinerva* (three-nerved sandwort) (Figure 4.1 D), a tree-bud scale and a few small twig fragments (the largest measuring 12mm in length and 1.5 mm in diameter). Finally, some charcoal remains (all <3mm in size) also comprise part of the assemblage.

The macrofossils from Sample 1 demonstrate a fairly good-level of preservation, as evidenced by the retention of fragile perianth-bristles on the nutlets of *Schoenoplectus* t*abernaemontani* and the clearly visible cell patterns on the seeds of *Juncus.* Species identification of *Schoenoplectus tabernaemontani* was made based on the length of the perianth-bristles and the less pronounced central ridge of the nutlets. The internodal plates required a little research for their proper identification. The obvious presence of vascular bundles, however, led to a confident assessment that they constitute the 'plates' from a nodal position in the stem of a monocotyledon, as described by Rudall (1994, 19-20). Finally, *Moehringia trinerva* was identified due to the slightly tapered margins of the seeds and the cell pattern running laterally across this margin instead of adjacent to it.

4.2 SAMPLE 2 (144-142CM): TRANSITION

The macrofossils retrieved from this horizon indicate a similar environment to Sample 1, but with slight increases and decreases of certain components. The local ecology continues to reflect overall damp conditions, with rushes again dominating the assemblage. The number of *Schoenoplectus tabernaemontani* fossils, however, severely decrease, while Juncaceae seeds increase. The absence of monocotyledon internodal plates suggests a reduction of grasses in the immediate area and the lack of obligate aquatic taxa hints at a hiatus in shallow pooling. The loss of *Ruppia maritima* as an indicator of local salinization is replaced by another halophyte, *Cochlearia officinalis* (common scurvygrass) (Figure 4.2 A). Both seeds and pod halves of this taxon were recovered from the sediment of this horizon; together with an increase in seeds from the halophytic *J. gerardii*, these remains indicate a continuation of brackish environmental conditions.

Other plant taxa indicative of a damp local environment, such as *Lychnis flos-cuculi* and cf. *Sagina sp*., persist in Sample 2. The number of recovered fossils for these taxa increases, however, suggesting an overall augmentation in their local presence. Sporangia of *Dryopteris*-type ferns and seeds of the *Viola* genus remain at relatively the same level across the two samples. *Montia fontana ssp. fontana* (blinks) (Figure 4.2 B), *Stellaria holostea* (greater stitchwort) and *Ranunculus subg. ranunculus* (buttercup family) all comprise new arrivals to the area. *Stellaria holostea*, along with the continued presence of *Moehringia trinerva*, still suggests some canopy cover in the vicinity. Twigs and wood fragments (the largest measuring 13mm x 10mm) confirms the local presence of woody taxa. The decrease in the overall number of shade tolerant taxa, however, combined with a decrease in *Betula* fruits, may reflect a slight reduction in woodland composition. *Atriplex* and *Rumex* achenes are still present, while *Urtica dioica* is absent. Finally, the number of charcoal fragments also decreases by 50% in this transitional sample.

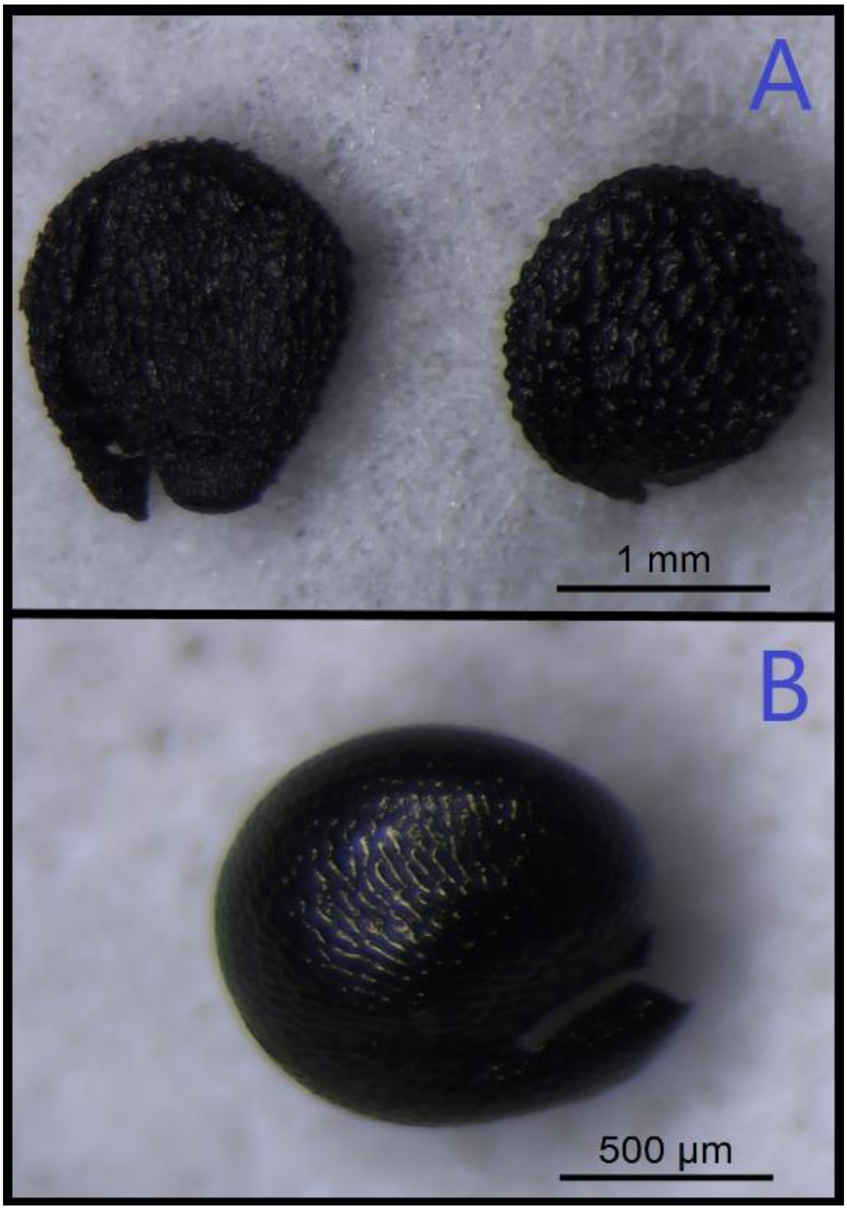


Figure 4.2: Some ecologically important fossil taxa recovered from Sample 2 (144-142cm): the halophytic *Cochlearia officinalis* (A) and the damp ground indicator *Montia fontana* ssp. *fontana* (B).

Like Sample 1, Sample 2 was also characterized by a high-level of preservation. The *Juncus* seeds were so well preserved that different cell patterns and the presence of raised tooth projections could be discerned even under low-powered microscopy. The establishment of species-level identifications and a group-type for *Juncus* seeds derived from this sample, which were then applied to the *Juncus* remains from the other two horizons. After grouping the seeds based on similar typology, a seed from each type was split and mounted on a microscope slide for viewing under the high-powered microscopy. Comparison with the reference collection at the Leiden University archaeobotanical laboratory and consultation with identification keys compiled by Köber-Grohne (1964) facilitated the recognition of two *Juncus* species based on size, shape, cell pattern and the presence of toothed projections. All *Juncus* seeds unable to be identified to species-level (due to the limitations of the reference collection) were recorded as either Type A or *Juncus sp*. Descriptions of the identified *Juncus* species and type are as follows:

Juncus articulatus: Seeds of this taxa measured c. 0.65mm x 0.4mm and had a somewhat bulbous tip. They stood out under low-magnification due to their distinctive square, ladder cell pattern. High magnification analysis revealed the presence of small toothed projections and thin, lateral cells with bowed walls and thickenings at the points where cell walls joined. The thickened points appeared as lines of dots under high magnification. These observations concur with both the description and images of *J. articulatus* provided by Köber-Grohne (1964, 34-35) (Figure 4.3).

Juncus gerardii: These fossils appeared very large and squat compared to other *Juncus* seeds, measuring c. 0.5mm x 0.4mm. They displayed thin, lateral cells in ladder formation superimposed by elongated, longitudinal cells with a blatant thickening of the margins under low-magnification. High magnification showed more clearly the stretched honeycomb-shaped nature of the lateral cells and confirmed the absence of any toothed projections. These components matched the criteria outlined by Köber-Grohne (1964, 35-36), allowing for a secure *J. gerardii* identification (Figure 4.4).

Juncus Type A: This type of *Juncus* seed was defined under low-magnification by its lateral, stretched honeycomb-shaped cells without marginal thickening (Figure 4.5 A). These seeds were of similar size to *J. articulatus*, but appeared pointed at both ends. High magnification revealed the presence of long, curved toothed projection (Figure 4.5 B). No species-identification was securely made for this type of *Juncus* fossil due to a lack of comparative material in the reference collection.

The fossils of *Cochlearia officinalis* were distinguished from the seeds of Caryophyllaceae based on their elongated noses, as well as the style and pattern of their papillae. Species-level identification was obtained through comparison with reference material, which confirmed that the papillae of *C. danica* were too big to match those observed on the recovered fossils. The features of these seedss, however, accurately corresponded to all the morphological characteristics of *C. officinalis*. Any fossils in which some of these morphological characteristics could

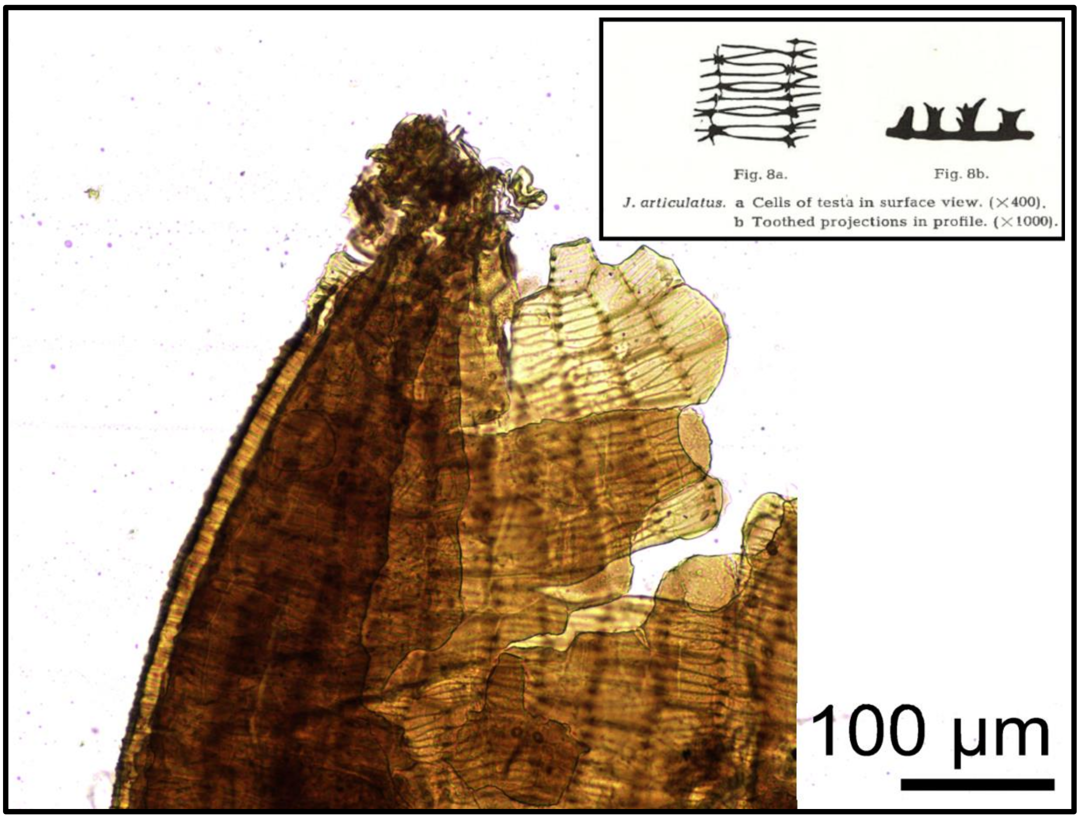


Figure 4.3: *Juncus articulatus* fossil recovered from Sample 2. Note the comparison with *J. articulatus* identification key by Köber-Grohne (1964, 35) (top right).

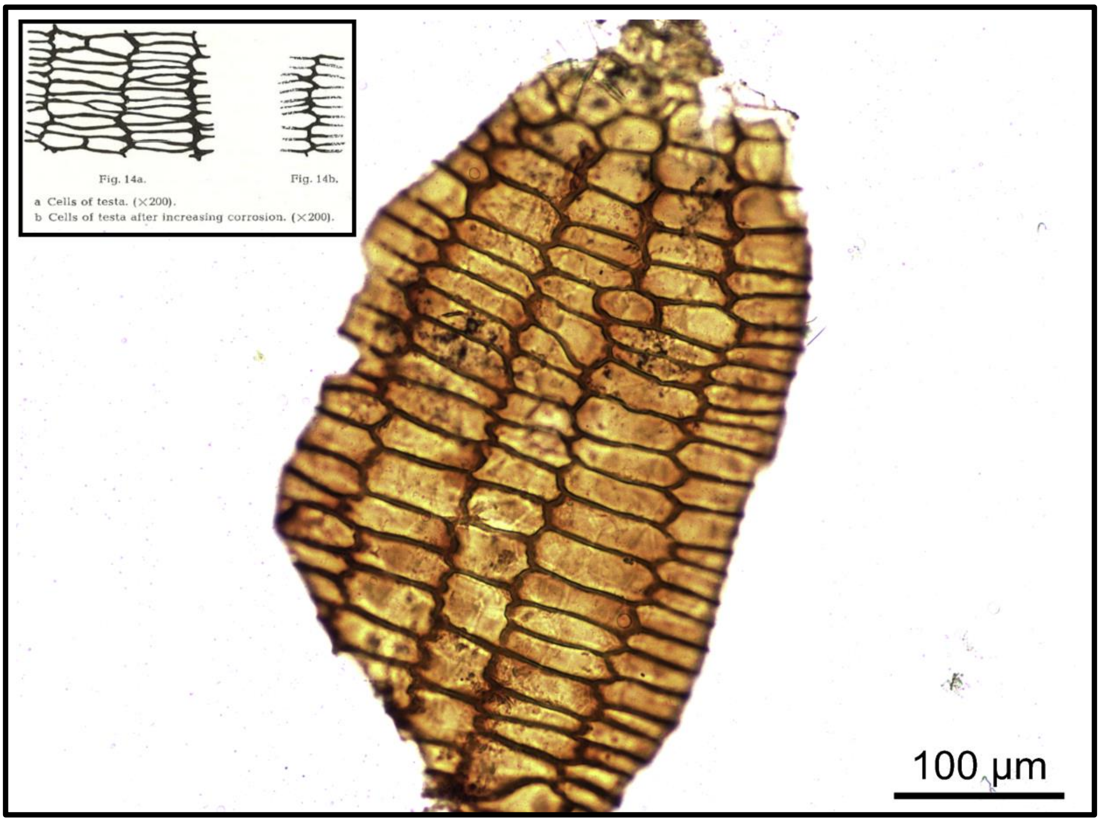


Figure 4.4: *Juncus gerardii* fossil recovered from Sample 2. Note the comparison with *J. gerardii* identification key by Kber-Grohne (1964, 36) (top left).

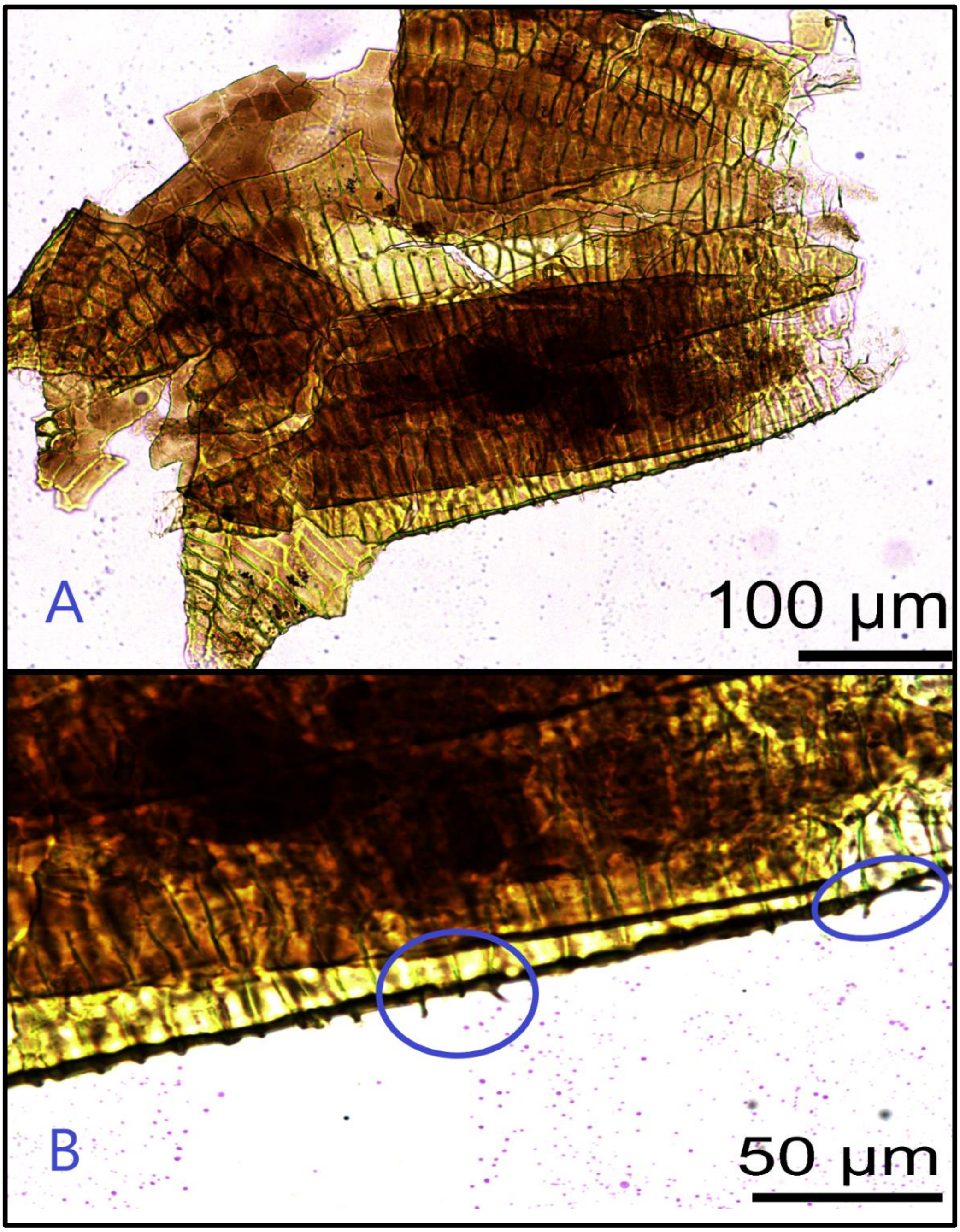


Figure 4.5: *Juncus* sp. Type A recovered from Sample 2. Note the stretched honeycomb-shaped cells without marginal thickening (A) and long toothed projections (B - blue circles).

not be confidently observed were recorded as cf. *C. offinicalis*. Fossil seeds of *Montia Fontana ssp. fontana* were easily identified down to subspecies-level based on their cell pattern and the lack of raised tubercles, as outlined by Stace 1997 (156-157).

4.3 SAMPLE 3 (104-102CM): EARLY NEOLITHIC

The plant fossil assemblage from this final horizon differed noticeably from the previous two samples, despite continuing to indicate an overall wet local environment. Rushes and sedges again dominate the flora, though they are now represented by different taxa. *J. gerardii* disappears, while the frequency of *J. articulatus* seeds remains the same and *Juncus* Type A seeds increase markedly. *Schoenoplectus tabernamontani* is also no longer present, but replaced by *Carex dioica* (dioecious sedge). Seeds of *Eleocharis sp.* reappear after their absence in Sample 2*.* The occurrence of shallow pooling is again suggested by the presence of new obligate aquatic taxa, such as *Potamogeton polygonifolius* (bog pondweed) (Figure 4.6 A), *Menyanthes trifoliata* (bogbean) (Figure 4.6 B) and *Callitriche sp.* (starwort) (Figure 4.6 C). While some species of this last taxon are considered semi-terrestrial, most are confined to water (Blamely and Grey-Wilson 1989, 330). Despite the lack of a species identification (which is difficult with *Callitriche* seeds), it is assumed that the *Callitriche* seeds from this sample likely represent a water species given the presence of other obligate aquatics in the assemblage. Halophytic taxa are conspicuously absent.

Lychnis flos-cuculi and cf. *Sagina sp*. remain present across the three samples as indicators of damp ground, while *Ranunculus* subg*. ranunculus* persists from Sample 2. The number of cf. *Sagina sp*. seeds, however, drastically increase in this sample. Several new herbaceous taxa indicative of damp ground appear in this assemblage, including *Mentha* cf. *aquatica* (water mint), *Potentilla palustre* (marsh cinquefoil) and *Selaginella selaginoides* (lesser clubmoss). *Circum sp.* (thistles) and *Lychnis cf. viscaria* (sticky catchfly) also comprise two new additions to the local flora. *Atriplex sp.* and *Rumex sp.* disappear, while *Urtica dioica* reappears and *Viola sp*. remains present. Shade-tolerant taxa are altogether absent, but a continued woodland presence is confirmed by the remains of *Betula sp*. fruits and a catkin scale, unidentified tree-bud scales and whole tree buds, as well as a significant increase in wood fragments. Both twigs and large chunks of wood (the largest measuring 70mm x 20 mm) form part of this wood-fragment assemblage. A final difference between this sample and the two previous samples pertains to the complete disappearance of *Dryopteris*-type fern sporangia and charcoal remains.

The level of preservation for Sample 3 appeared to be somewhat less than that observed for Sample 1 and 2. The overall higher number of indet. seeds, seed fragments and unidentifiable *Juncus* fossils supports this notion (Table 4.2). On the whole, however, preservation was still good and some *Carex dioica* nutlets were recovered with their utricles still intact. While the diagnostic noses of these utricles

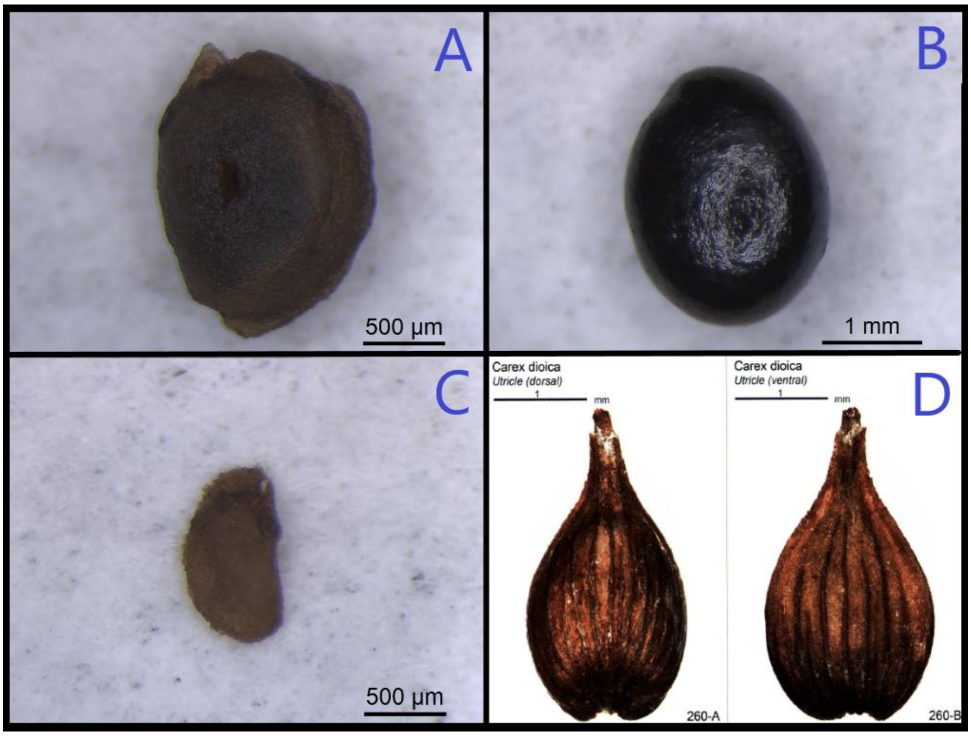


Figure 4.6: Ecologically important fossil taxa recovered from Sample 3 (104-102cm): A-*Potamogeton polygonifolius*; B-*Menyanthes trifoliata*; C- *Callitriche sp.*; and an image of *Carex dioica* from Cappers et al. (2012, 54) showing morphologically distinct utricle creases (D).

were all missing, the distinctive creases extending upward from the base (Figure 4.6 D) allowed for a confident identification upon comparison with reference material. Additionally, the species-level identification of *Potamogeton polygonifolius* required some extra analysis in order to distinguish it from its close relative *P. coloratus*. The number of fruits present in the assemblage provided a population on which biometrics could be employed. This methodological approach facilitated their secure identification as *P. polygonifolius,* based on the slight size difference between the two species.

Table 4.2: Comparison of sample assemblage preservation. Sample 3 clearly shows the poorest level of preservation.

	Sample 1 (188-186cm)	Sample 2 (144-142cm)	Sample 3 (104-102cm)
Indet seeds	3	1	12
Seed fragments	12	4	7
Juncus sp. fossils	4	114	595

Chapter 5:
Synthesis and Discussion

The results presented in the previous chapter are here synthesized into a reconstruction of Orcadian palaeoenvironment at the Bay of Ireland site from the late Mesolithic to the early Neolithic. This interpretation of the data considers aspects of palaeoenvironmental investigations such as the role of taphonomy in the creation of macrofossil assemblages and influential factors for vegetational succession. These topics segue into discussions concerning prehistoric woodland presence and the management of vegetation by hunter-gatherers. Finally, in order to fully assess the quality of the reconstruction and its contribution to Orcadian palaeoenvironmental research, this chapter concludes by comparing the results obtained by this study with those previously conducted both at the Bay of Ireland site and on Orkney as a whole.

5.1 PREHISTORIC ENVIRONMENT AND VEGETATIONAL SUCCESSION

The ecological information associated the macrofossil evidence from this study (Table 5.1) suggests that the area around the site at the Bay of Ireland consisted of a wetland dominated by tall vascular plants, such as reeds and sedges, for most of Orkney's early prehistory. Previous deposits of glacial till likely rendered the soil of poor drainage quality (Jackson et al. 2014, 29), which, in combination with low-relief Orcadian topography, allowed for the development of a wetland by at least the Late Mesolithic – if not earlier. The presence of halophytic taxa at this time (Sample 1) indicate that tidal action contributed to the inundation of the site, probably along with some precipitation and seepage from ground water due to a high water table relating to sea-level rise over the previous centuries (Figure 5.1). The input from the sea, as a water source for this wetland, allows for its description as a tidal saltmarsh (Sharitz et al. 2014, 17; Tiner 2013, 1 & 46).

Indeed, several taxa typical of saltmarshes feature in the fossil assemblage from this horizon: most notably, *Ruppia maritima* and *Juncus gerardii* (Sharitz et al. 2014, 17; Tiner 2013, 59 & 82). As a submergent, *R. martima* indicates that the marsh featured some shallow pooling in addition to saturated ground. This elevated

Table 5.1: Habitat ecologies for plant species identified during this analysis. Ecological descriptions after Stace 1997.

Taxa	Stace Ecology Descriptions	Page #
Carex dioica	"base-rich bogs and flushes"	814
Cochlearia officinalis	"salt marshes, cliffs and other habitats by or near sea and by salt-treated roads inland"	266
Juncus articulatus	"damp grassland, heaths, moors, marshes, dune-slacks, margins of rivers and ponds"	788
Juncus gerardii	"salt-marshes and inland saline areas"	784
Lychnis flos-cuculi	"marshy fields and other damp places"	173
Lychnis cf. viscaria	"cliffs and rocky places"	174
Mentha aquatica	"marshes, ditches, wet fields and by ponds"	574
Menyanthes trifoliata	"in shallow water, bogs and fens"	538
Moehringia trinerva	"shady places in woods and hedgebanks"	160
Montia fontana	"many kinds of damp places, from streams to seasonally damp hollows"	156
Potamogeton polygonifolius	"shallow ponds, bogs, ditches, small streams, on acid soils"	768
Potentilla palustre	"fens, marshes and bogs"	342
Ruppia maritima	"in brackish ditches and pools; local round most coasts of Britain and Ireland"	773
Schoenoplectus tabernaemontani	"in similar places to S. lacustris but also in marshes, dune-slacks and wet peaty places, mostly near sea" NOTE: L. lacustris "in shallow water of lakes, ponds, slow rivers, canals and dykes"	800
Selaginella selaginoides	"damp places among moss and short grass on mountains"	6-7
Stellaria holostea	"woods and shady hedgerows"	162
Stellaria media	"ubiquitous weed of cultivated and open ground"	162
Urtica dioica	"in many habitats, especially woodlands, fens, cultivated ground and where animals defecate"	117

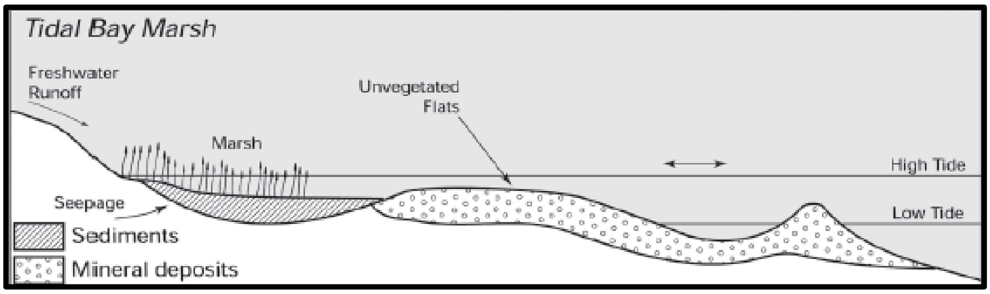


Figure 5.1: Water sources for a tidal salt marsh (Tiner 2013, 20).

degree of inundation probably occurred close to the coast, where high wave action from storms helped create the brackish wetland. The salinity level within this salt marsh was likely low and decreased in relation to distance from the shore, allowing for the presence of halophytes, as well as salt-intolerant, hydrophytic vegetation. While non-halophytic taxa can survive in salinity levels of 3ppt or lower, they tend to inhabit the upper edges of brackish wetlands near fresh water runoff (Tiner 2013, 88-89). Accordingly, *Juncus articulatus*, *Lychnis flos-cuculi* and *Scheonoplectus tabernaemontani* probably grew along the fringes of the marsh's pooling, while emergent, herbaceous taxa occupied the damp, less saline ground that extended out from these pools. *Moehringia trinerva* also inhabited this intermediate area, though likely closer to the periphery of the marsh, where the woodland's canopy offered some shade.

The overall lack of wood fragments, as well as the presence of only *Betula* fruits and no catkin scales, supports the notion that woodland featured along the periphery of the marsh during the late Mesolithic. While the greatest number of *Betula* fruits was recorded for this horizon, these fossils have wings that lend themselves to wind transport (Figure 5.2). Their presence, therefore, results from taphonomic bias. Storm winds that caused tidal inundation of the site are likely also responsible for the abundance of *Betula* fruit amongst the fossil assemblage at this time. The lack of catkin scales, which are not subject to the same transport biases, distinctively suggests that *Betula* trees did not inhabit the immediate area. The sensitivity of temperate trees to salinity levels (Tiner 2013, 88), explains the peripheral woodland. Thus, the wetland flora demonstrates a vegetation gradient commonly observed within many salt marshes (Figure 5.3) (Sharitz and Pennings 2014, 135).

Figure 5.2: *Betula* fruits recovered from the late Mesolithic (Sample 1). The fossil on the left shows preservation of a 'wing' feature which facilitates the fruits' ability to be transported by wind.

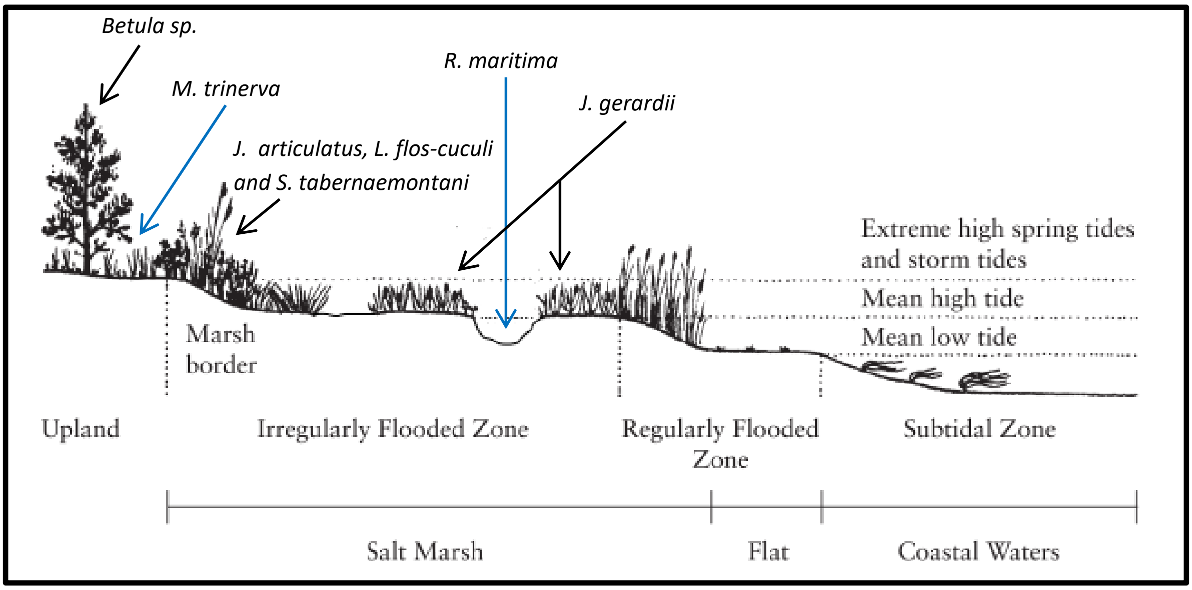


Figure 5.3: The distribution gradient of vegetation within a salt marsh (after Tiner 2013, 116).

A comparison of sample taxa ecologies illustrates that after this point, the saltmarsh appears to lose some of its wetness (Table 5.2). A rise in hydrophytic taxa, such as *Juncus articulatus*, *Lychnis flos-cuculi* and *Montia Fontana* ssp. *fontana*, attests to a continuance of damp conditions, but there is no more evidence for shallow pooling. Instead, the assemblage dating to the transition between the late Mesolithic and early Neolithic periods (Sample 2) is dominated by emergent taxa. This change in local water depth could indicate the earlier formation of a coastal barrier that prevented further indundation of the wetland by the sea, allowing for the introduction of a new emergent halophyte: *Cochlearia officinalis*. Tides from prior storms may have also deposited sediment and additional organic litter within the wetland, which resulted in a higher substrate (Tiner 2013, 75 & 108). Either way, macrofossil evidence demonstrates a continuation of brackish conditions within the wetland.

The increase in halophytic fossils, however, should not be taken as evidence for increased salinity, since halophytes do not respond in this manner to changes in saline concentrations. This rise in saline tolerant seeds, *Juncus gerardii* and *C. officinalis*, represents the taphonomic bias of overrepresentation. *Juncus* species produce an extremely high number of seeds per plant, facilitating a greater recovery volume of their seeds compared to other plant taxa, while the recovery of *C. officinalis* pod halves denotes its presence within the immediate vicinity of the sampling point. Likewise, the decrease in *Betula* fruit values does not necessarily represent a reduction of *Betula* trees in the area. The recorded decline of this taxon

Table 5.2: Ecological habitat categorization of identified taxa. Coloured squares indicate positive (green), intermediate (yellow), and negative (red) phases for the most significant ecological changes that occurred at the Bay of Ireland site.

	General Type (after Stace)	Taxa	Sample 1 (188-186cm)	Sample 2 (144-142cm)	Sample 3 (104-102cm)
Ecology 1	Shade Tolerant	*Moehringia trinerva*	7	2	
		Stellaria holostea		1	
Ecology 2	Waterside/Damp Ground	*Carex dioica*			49
		Juncus articulatus	2	33	39
		Lychnis flos-cuculi	1	12	10
		Montia fontana		4	
		Mentha cf. aquatica			9
		Potentilla palustre			10
		Ranunculus subg. ranunculus		1	4
		Selaginella selaginoides			1
		Schoenoplectus tabernaemontani	289	11	
Ecology 3	Obligate Aquatic	*Callitriche sp.*			49
		Menyanthes trifoliata			2
		Potamogeton polygonifolius			27
		Potamogeton sp.	1		
Ecology 4	Halophytic	*Cochlearia officinalis*		13	
		Juncus gerardi	2	40	
		Ruppia Maritima (also obligate aquatic)	2		
Ecology 5	Unclassified	*Juncus sp. Type A*	2	26	366
		Lychnis cf. viscaria			1
		Stellaria media			1
		Urtica dioica	2		1
		All other taxa only indentified to genus-level	201	334	709

may be due to the influence of taphonomy; a decrease in storminess would also reduce winds, inhibiting the aeolian transport of so many *Betula* fruits to the site. The decreasing values of shade tolerant taxa, on the other hand, may indicate an opening up of the woodland canopy. Overall, however, the wetland remained fairly similar in both composition and appearance over the five centuries from c. 4,589 – 4,082 BC.

By the early Neolithic, the wetland had undergone a degree of vegetational succession. The process for this change may have already been underway half a millennium earlier, but its culmination resulted in a new ecological community dominated by fen vegetation c. 3,596 BC. A significant increase in obligate aquatics indicates renewed shallow pooling (likely 1m or less) within the wetland. The complete lack of halophytes, however, suggests that this wetland now comprised freshwater. A vegetational succession from halophytic taxa to salt-intolerant taxa is not without precedence. If local tidal inundation ceased to contribute a slat component to the wetland water, emergent halophytes may have provided enough cover to prevent water evaporation, allowing for ground water and precipitation to dilute the existing salinity within the wetland (Tiner 2013, 104; Sharitz and Pennings 2014, 140). This process of change was likely aided by an increase in regional precipitation and/or increased ground water seepage due to a rise in the water table.

The standing freshwater within the wetland was likely still or slow-moving, with low suspended sediments. These conditions facilitated the establishment of a new plant community in the area. Though there is much overlap between bogs and fens, this wetland can be termed a fen based on both the pH value of its water and the floristic taxa it supported (Sharitz et al. 2014, 12-13). Two plant species, *Potamogeton poligonifolius* and *Carex dioica*, provide a basis for determining the pH level of this early Neolithic wetland. While the vascular aquatic *P. poligonifolius* mainly inhabits oligotrophic waters, the sedge *C. dioica* prefers base-rich soils. The water, therefore, probably had a pH level close to the top end of oligotrophic – around 7 or 8 – since the underlying calcareous geology of the area and the previous oceanic contribution to soil saturation at the site suggest the presence of at least some nutrients (Tiner 2013, 66). A pH value in this range would support the presence of both *C. dioica* and *P. polygonifolius*, as the latter is not restricted to – merely prefers – extremely low-nutrient environments (Godwin 1975, 359).

Fens tend to be slightly more nutrient-rich than bogs, with a pH value ranging between c. 5 to 8, and support a higher diversity of plant life (Figure 5.4) (Sharitz et al. 2014, 13; van der Valk 2012, 19). The macrofossil evidence demonstrates that the Bay of Ireland site exhibited a higher number of plant taxa during the early Neolithic than previously (Table 5.3). This vegetation included various new plant species. The newcomers *Menyanthes trifoliate* and *Potentilla palustre* both comprise typical fen species and lend further credence to the presence of *P. poligonifolius*, since they constitute characteristic associates of this taxa (Preston 1995). The encroachment of *Betula* and *Salix* into the wetland at this time also agrees with fen characteristic, as bogs typically support shrubs and/or conifers, but not deciduous tree taxa (Sharitz et al. 2014, 13).

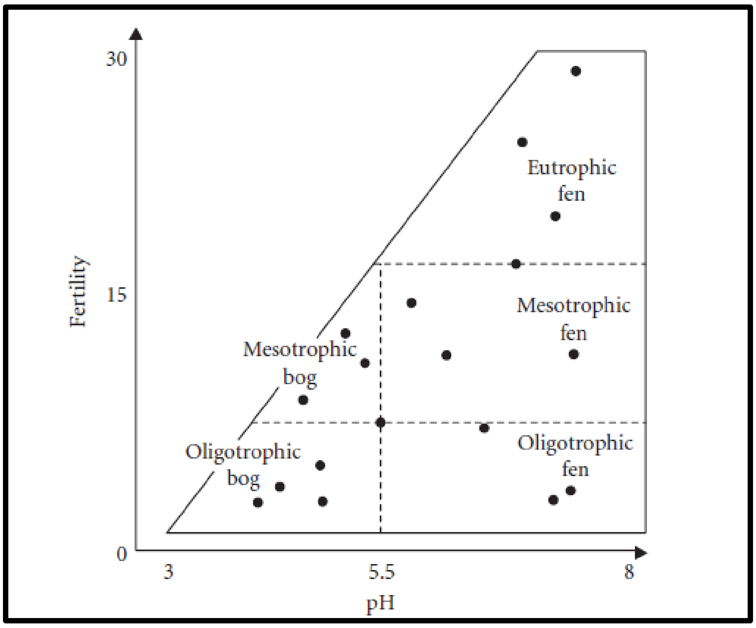


Figure 5.4: pH value range for bogs and fens (van der Valk 2012, 19).

Table 5.3: Number of taxa and fossils for each sample and ecology habitat.

	Sample 1 (188-186cm)	Sample 2 (144-142cm)	Sample 3 (104-102cm)	Sample 1					Sample 2					Sample 3				
Ecology Type				E1	E2	E3	E4	E5	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5
Number of Taxa	18	17	20	1	3	1	2	11	2	4	0	2	9	0	6	3	0	11
Number of Fossils	509	477	1278	7	292	1	4	205	3	60	0	53	361	0	118	78	0	1082

Thus, the palaeoenvironmental reconstruction for the Bay of Ireland suggests that the site initially comprise a tidal marsh during the late Neolithic period. This marsh received increased debris input from the sea as a result of stormy weather, which elevated the substrate within the marsh, decreasing the depth of pooled water for a period. The same movement of debris may have also created a barrier which thereafter prevented marine influence as a water source for the wetland, allowing it to transform into a freshwater fen by the early Neolithic period.

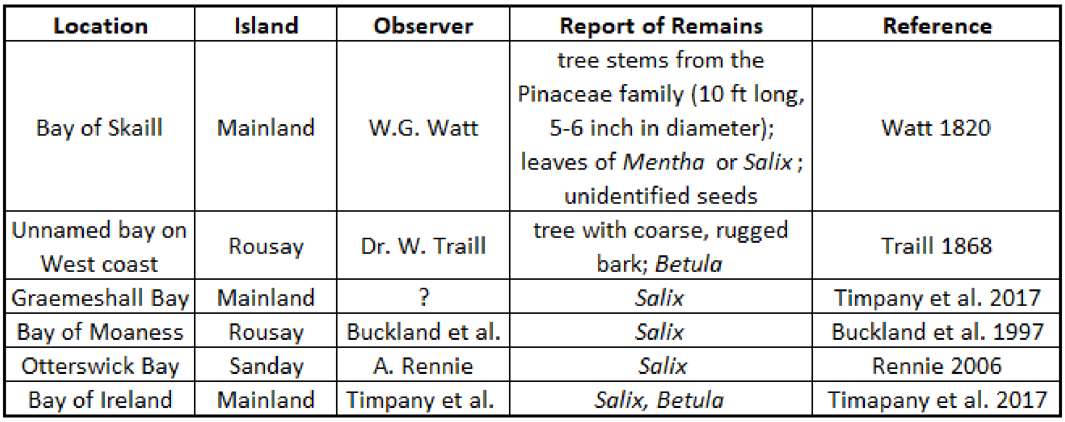
5.2 WOODLAND COMPOSITION

The composition of Orkney's prehistoric woodland has been a feature of debate for many decades. Due to palynological issues associated with the detection of tree taxa (Whittington and Edwards 2003, 15; Farrell et al. 2014, 232; Tipping 1994, 5 – see section 2 of chapter 1 for full details) and the dominant employment of pollen analysis as a proxy for Orcadian palaeoenvironmental research, this aspect of the woodland has yet to be fully resolved. Aside from *Betula*, *Corylus* and *Salix*, palaeoenvironmental research has been unable to securely establish the native status of other prehistoric tree taxa (Davidson et al. 1976, 350; Donaldson 1986, 11). The issue of long-distance pollen transport renders the pollen values of trees for prehistoric Orkney equivocal. Macrofossil analysis, however, has the benefit of providing secure evidence for the local presence of trees, since its findings denote the growth of trees in the immediate vicinity (Edwards and Whittington 2003, 64). The only caveat to investigating the composition of the Orcadian prehistoric woodland by means of a macrofossil analysis pertains to a suitable sample site – one which featured the past growth of trees within close proximity to point of sampling. The difficulty in identifying such a site may partly explain the low percentage of Orcadian palaeoenvironmental investigations that have considered macrofossil evidence to date. Hence, the discovery of the submerged forest remains at the Bay of Ireland provided an opportunity to employ macrofossil analysis as a means of potentially recovering secure evidence for other tree taxa components of Orkney's prehistoric woodland.

Unfortunately, the results of this macrofossil analysis revealed evidence for only one tree taxa – *Betula*. This tree constitutes a well-established component of Orkney's prehistoric woodland due to its commonly observed fossil remains (Bunting 1994, 784), including a 19th century account of *Betula* trees as part of an expanse of submerged forest on the coast of Rousay (Traill 1868, 150). The lack of evidence for other tree taxa in the macrofossil assemblage, however, may be due to a combination of taphonomy and the local nature of macrofossil investigations.

Several other reports of submerged forests, aside from the Bay of Ireland, exist for Orkney, of which *Salix* constitutes the most commonly recorded tree taxon (Table 5.4) (Timpany et al. 2017, 15). *Salix* stumps also form the majority of submerged forest remains at the Bay of Ireland. Interestingly, Sample 3 (104-102cm), which corresponds to the radiocarbon dates for the willow stumps, did not produce any *Salix* fossils. The lack of evidence for a tree taxon known to have been growing in the immediate vicinity at the time and point of sampling indicates another common issue of taphonomy – underrepresentation. This taphonomic bias refers to the selective exclusion of certain taxa fossils from an assemblage due to

Table 5.4: List of Orcadian submerged forests.



Location	Island	Observer	Report of Remains	Reference
Bay of Skaill	Mainland	W.G. Watt	tree stems from the Pinaceae family (10 ft long, 5-6 inch in diameter); leaves of *Mentha* or *Salix*; unidentified seeds	Watt 1820
Unnamed bay on West coast	Rousay	Dr. W. Traill	tree with coarse, rugged bark; *Betula*	Traill 1868
Graemeshall Bay	Mainland	?	*Salix*	Timpany et al. 2017
Bay of Moaness	Rousay	Buckland et al.	*Salix*	Buckland et al. 1997
Otterswick Bay	Sanday	A. Rennie	*Salix*	Rennie 2006
Bay of Ireland	Mainland	Timpany et al.	*Salix, Betula*	Timapany et al. 2017

factors such as preservation, transport processes or low seed production rates. The macrofossils of *Salix* are often affected by this feature of taphonomy and it is possible that other tree taxa were too.

One particular tree taxon which may have been present as a component of the prehistoric Orcadian woodland, but escaped detection by the macrofossil analysis, is *Alnus*. This tree has an affinity for wetland habitats and is often featured among the tree pollen values of Orcadian palaeoenvironmental investigations. The wetland ecology of the Bay of Ireland would have been an ideal environment for the growth of *Alnus*, since this tree taxon cannot only withstand brackish water conditions (de la Vega-Leinert et al. 2007, 767), but also specifically occupies "brackish-freshwater transitions in estuaries and sea lochs" as part of its habitat niche (Bennett and Birks 1990, 124). It is also commonly found in association with the presence of Betula and Salix (Bennett and Birks 1990, 124). Given these factors, de la Vega-Leinert et al. (2007, 767) accepted the low, consistent pollen values recorded for *Alnus* at Scapa Bay as evidence for its local prehistoric growth on Orkney. This site featured the same ecological evolution of brackish to freshwater conditions as the Bay of Ireland. Furthermore, Farrell (2015) also believes that pollen evidence from Hobbister (site B) denotes the local growth of *Alnus* on prehistoric Orkney. This evidence consists of a sharp rise in *Alnus* pollen among mostly low levels of other tree taxa values (Figure 5.5), suggesting the establishment of an *Alnus* stand in the nearby area (Farrell 2015, 476).

It is conceivable, therefore, that *Alnus* may have been present among the flora of the submerged forest at the Bay of Ireland, but taphonomically underrepresented in the macrofossil assemblage. If this tree had only colonized the wetland within the decades leading up to the date of Sample 3 (c. 3,596), then its fruits would not have featured in the macrofossil assemblage due to the time lag required for its seed production. *Alnus* only begins to produce fruits 40 years after its establishment (Bennett and Birks 1990, 124). Even if the tree was present prior to this date, the point of sampling may have simply been devoid of its fossil evidence. The absence of *Alnus* fruits at the precise sample location could result from the occurrence of taphonomic transport or a lack thereof. *Alnus* fruits are readily susceptible to water transport (Bennet and Birks 1990, 124). The movement of water at the site may have transported its fruits away from the point of sampling. Conversely, *Alnus* fruits are not as wind-adapted as *Betula* fruit. If this tree also existed along the fringes of the wetland, its fruits may not have reached the point of sampling.

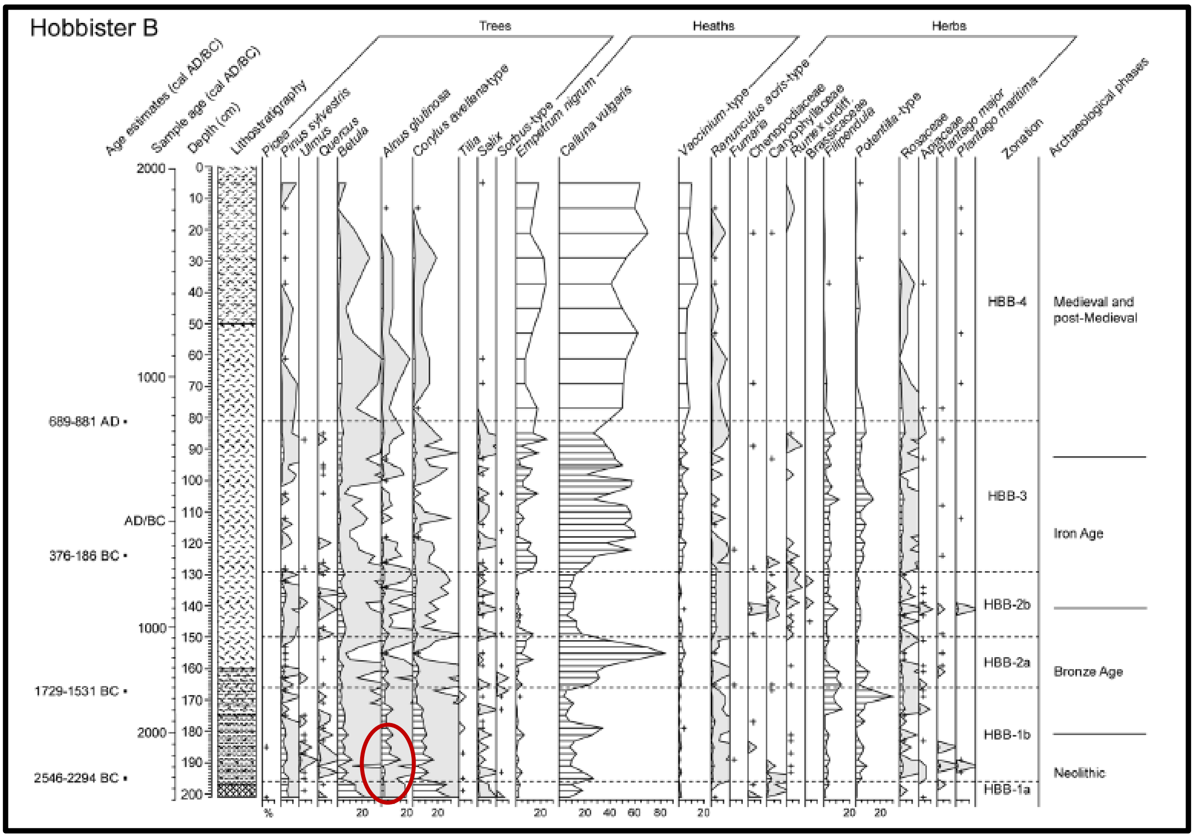


Figure 5.5: Pollen diagram for Hobbister site B showing late Neolithic rise in *Alnus* (after Farrell 2015, 474).

Thus, while the results of the Bay of Ireland macrofossil analysis did not provide any new evidence for the native status of prehistoric tree taxa on Orkney, in this case the absence of evidence cannot be considered evidence of absence. The remains of *Salix* stumps at the site attests to the fact that other tree taxa, aside from *Betula*, may have been present but gone undetected by the macrofossil analysis. And so, the debate surrounding the woodland composition of prehistoric Orkney continues.

5.3 EVIDENCE FOR HUMAN-PLANT INTERACTION

The Bay of Ireland samples produced some results that are often considered indicative of human-plant interactions, including a decrease in tree values (*Betula*), a small amount of microscopic charcoal remains and some ‘synanthropic’ plant fossils (*Rumex and Atriplex*). Together with the discovery of an oak plank at the site – which was tentatively assigned an anthropogenic origin (Timpany et al. 2017, 21) – these results appear to suggest human impact on the local flora. Anthropogenic activity, however, is not interpreted as having influenced the prehistoric wetland ecology or vegetational succession at the Bay of Ireland. For, these macrofossil results actually stem from natural ecological conditions and biased taphonomic processes, while the nature of the oak plank remains ambiguous.

Pre-Neolithic human-plant interactions largely comprise late Mesolithic disturbances to the local woodland (Brown 1997, 135; Farrell et al. 2014, 230-231). These disturbances are recognized in pollen diagrams by decreased values of tree taxa (Figure 5.6) and are often interpreted as Mesolithic management of the vegetation (Brown 1997, 135). The Bay of Ireland samples demonstrate an increasing reduction in *Betula* fruit values from the late Mesolithic into the early Neolithic. This decrease, however, likely represents the effects of taphonomy. For, the assemblage contained far greater numbers of *Betula* fruits as opposed to catkin scales, indicating that birch trees existed at a distance, along the margins of the wetland. The presence of *Betula* fruits, therefore, results from wind transport, since these fossils have adapted to travel via aeolian processes (cf. section 5. 1). Given that the transition from Mesolithic to Neolithic has been described as a period of declining storminess on Orkney (de la Vega-Leinert et al. 2000, 525), the *Betula* values most likely result from decreasing winds associated with this weather. Thus, the decrease in *Betula* fossils at the site is interpreted as the product of taphonomic bias and not a reduction in actual birch trees.

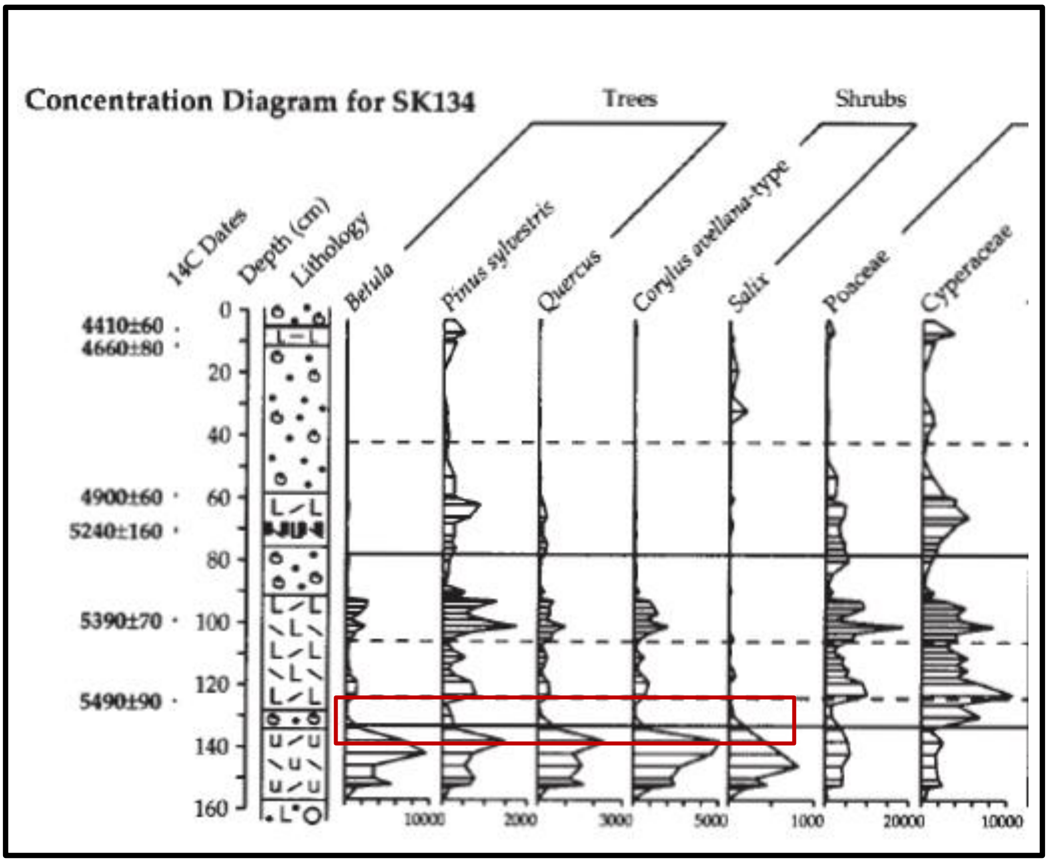


Figure 5.6: Portion of the pollen diagram for the Bay of Skaill showing Mesolithic woodland disturbance (after de la Vega-Leinert et al. 2000, 519).

Microscopic charcoal particles also constitute remains that are often interpreted as evidence for human-plant interactions during the Mesolithic period (Innes et al. 2013, 81; Timpany et al 2017, 16). It is believe that hunter-gatherers used fire to manage the local vegetation as both a hunting and plant cultivation strategy (Innes et al. 2013, 81; Smith 1970, 81-83; Tinsley 1975, 17; Tipping 1994, 17 – see section 2.3 for more details). Microscopic charcoal remains, however, are highly susceptible to issues of taphonomic transport. Given the low-density and buoyancy of charcoal, microscopic particles are readily displaced by means of both wind and water (Kukulak 2014, 302; Nichols et al. 2000, 44; Scott 2010, 16). In fact, charcoal residues from fires originating in Australia have been recovered from sediment horizons in New Zealand (Butler 2008, 126), attesting to the great distances that wind can carry microscopic charcoal remains. Since the Bay of Ireland comprised a wetland created by marine influence during a period of stormy weather, it seems likely that the small amount of microscopic charcoal remains recovered from the samples arrived at the site via strong winds or rough seas. de la Vega-Leinert et al. (2007) drew the same conclusion for the charcoal particles observed during the pollen analysis of the prehistoric tidal lagoon at Scapa Bay.

They determine that these remains derived from sea transport (de la Vega-Leinert et al. 2007, 766). Thus, the presence of microscopic charcoal remains at the Bay of Ireland, whose values also decreases over time, is interpreted as the result of taphonomic processes associated with ameliorating weather conditions, rather than evidence of human-plant interactions.

The Bay of Ireland samples also produced some fossils from plants considered to be 'synanthropic' taxa. These fossils comprise *Atriplex sp*. and *Rumex sp*. achenes (Figure 5.7). A fundamental point to remember about all 'synanthropic' plant taxa, however, is that they became indicators of cultivation due to their association with agricultural practices of the Neolithic (Innes et al. 2013, 81). The large-scale ground disturbance involved in farming increased the available habitation area of these plants. 'Synanthropic' taxa, however, existed among the natural flora before the advent of agriculture, albeit in low numbers due to limited natural disturbances of the ground (Brown 1997, 135). While certain taxa are widely accepted as indicative of anthropogenic activity, such as *Plantago lanceolata* (Innes et al. 2013, 81), others are not. For example, *Rumex* does not necessarily indicate human activity (Tipping 2004, 48). It can also indicate a coastal environment, since certain species within this plant genus have adapted to withstand the effects of salt spray from the sea (Tiner 2013, 106). Likewise, *Atriplex* can also indicate disturbed ground or a coastal area, depending on the species (Blamey and Grey-Wilson 1989, 76). Therefore, without species identifications, which are difficult to determine for both taxa due to overlap in achene morphology, one cannot be certain of the ecology these taxa denote. Since, however, "certain species of *Rumex* and *Atriplex* can be invasive taxa to tidal wetlands" (Tiner 2013, 118) and *Atriplex* features among the small suite of plants that dominate saltmarshes (Sharitz et al. 2014, 17), their presence within the Bay of Ireland assemblage seems to reflect the natural prehistoric environment of the site.

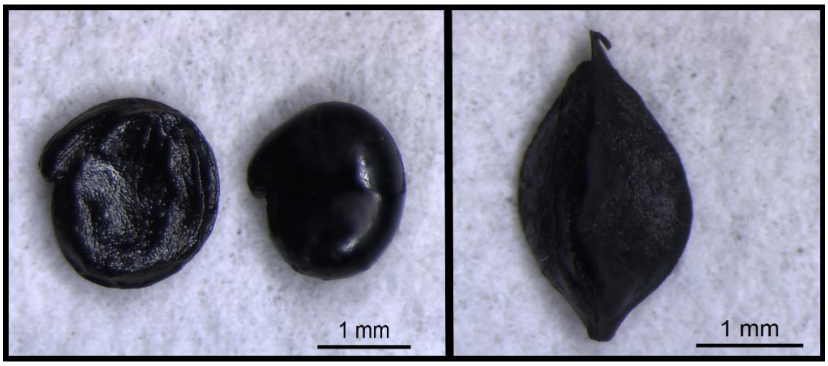


Figure 5.7: Recovered fossils of *Atriplex sp*. (right) and *Rumex sp*. (left).

Prior to this macrofossil analysis, an oak plank was found stratified within the intertidal peat at the Bay of Ireland. This piece of wood, which dates to the Mesolithic period, was determined to represent a "radially half split log" with tapered ends (Timpany et al. 2017, 5 & 17). A detailed examination of the log, however, revealed no evidence for anthropogenic working or dressing of the wood (Timpany et al. 2017, 5). The effects of erosion may have contributed to this lack of anthropogenic evidence, since the log appears to have undergone a period of exposure to the sea (Timpany et al. 2017, 5). Nevertheless, without evidence for human interaction with the wood, its anthropogenic origin remains somewhat questionable. Given the coastal nature of the site, the log also could have arrived at the Bay of Ireland as driftwood – a common feature of both the prehistoric and modern Orcadian environment (Donaldson 1986, 14; Farrell 2015, 475; Farrell et al. 2014, 232; Keatinge and Dickson 1979, 586). In fact, the log matched dendrochronologically to an oak in Northern Ireland, lending support to this notion (Timpany et al. 2017, 20).

Thus, none of the plant macrofossils recovered from Bay of Ireland indicates any human-plant interaction at the site between the late Mesolithic and early Neolithic periods. The results also serve as a cautionary example to carefully consider the full ecological conditions suggested by plant fossil assemblages and the taphonomic processes that may have affected them, since the presence of possible anthropogenic indicators does not necessitate human-plant interactions.

5.4 COMPARISON WITH PREVIOUS BAY OF IRELAND RESULTS

Prior palaeoenvironmental work at the Bay of Ireland site includes a late Mesolithic multidisciplinary investigation, involving pollen, waterlogged plant remains and non-pollen palynomorphs analyses, by Timpany et al. (2017) and a late Mesolithic – early Neolithic coleopteran study by Buhat (2018). In terms of vegetational ecology, the results from the current macrofossil analysis agrees well with the findings from these other studies; though some differences of interpretation exist regarding certain aspects of the prehistoric environment.

The work by both Timpany et al. (2017) and Buhat (2018) suggest that the prehistoric environment at the Bay of Ireland site comprised a reedswamp with shallow ponded water and marginal woodland (Timpany et al. 2017, 15). The presence of foraminifera, coastal vegetation, a non-pollen palynomorph indicative of marine influence and the presence of halophytic beetle taxa also indicate periodic inundation by the sea (Buhat 37-38; Timpany et al. 2017, 13-15). While Timpany et al. (2017, 15) concluded that "a salt marsh may have lain close by," the current macrofossil results suggest that the site actually consisted of a saltmarsh. This slight difference in interpretation could stem from the fact that Timpany et al. (2017) analysed sediment samples from a different test pit at the site. Given the interpreted vegetation gradient of the saltmarsh and the distance separating the two test pits, it is conceivable that Timpany et al. (2017) analysed samples closer to the margin of the marsh where a source of freshwater input may have had more of an influence on the immediate vegetation. Such a possibility would account for the lack of halophytic taxa within the fossil assemblage recovered by Timpany et al. (2017) (Figure 5.8). The significant rise, later in the profile, of herbaceous taxa tolerant of sea spray and/or low salinity levels, such as *Chenopodium*, *Rumex*, and *Atriplex* (Tiner 2013, 90 & 106; de la Vega-Leinert et al. 2012, 765-766), could reflect the onset of the stormy weather that was interpreted by current macrofossil analysis.

Interestingly, the work by Buhat (2018, 36-37), which analysed sediment samples from the same test pit as the present investigation, not only recovered beetle evidence for periodic sea inundation, but also recovered beetle taxa indicative of a "sandy terrain." These beetles, *Xantholinus linearis and Omalium sp*., only appear in the stratigraphic sequence from 150-130cm (Appendix 4), which perfectly overlaps with Sample 2 (144-142cm) of the current macrofossil analysis. The habitat preference for these beetles supports the interpretation that the salt marsh's substrate was elevated at this time by an increase in sediment deposition related to strong gales. This same evidence also corroborates the notion that a potential sand barrier had also formed by this period as a result of stormy weather. Thus, the three Bay of Ireland investigations accord well in terms of the general vegetational ecology present at the site during early prehistory.

This current macrofossil analysis, however, differs greatly from the other two studies in respect to its interpretation of limited – to no – human-plant interactions and animal grazing at the site. Timpany et al. (2017, 21) and Buhat (2018, 57) both interpret significant human activity within the wetland. Timpany et al. (2017) believe that the recovery of charcoal indicates management of the reedswamp vegetation by Mesolithic people, while the present investigation, attributed these remains to processes of taphonomy, rather than human-plant interactions. Unfortunately, Timapny et al. (2017) did not provide the exact size

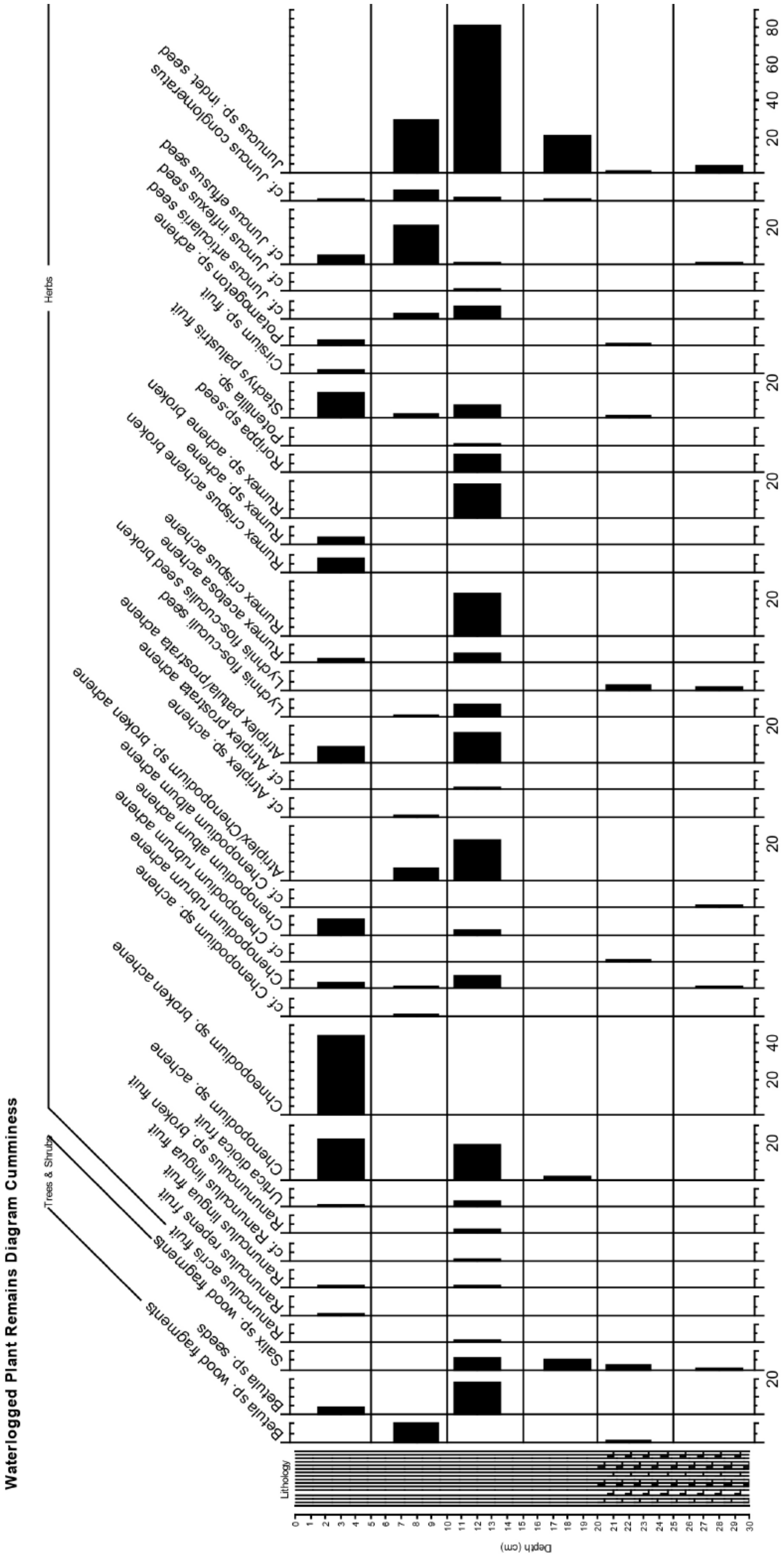
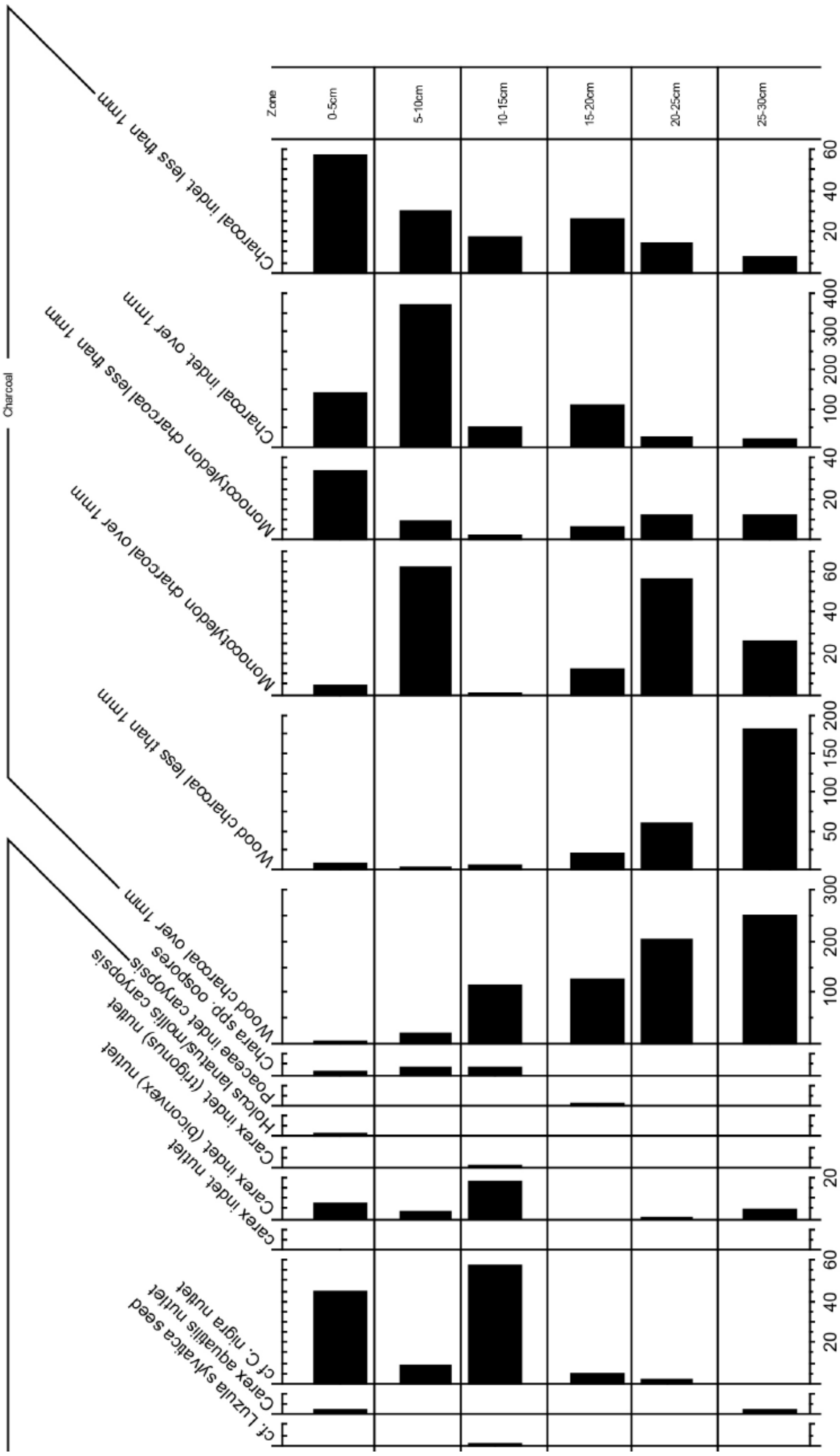


Figure 5.8: Bay of Ireland macrofossils from Test pit 1 (Sharpe 2014, 40; Timpany et al. 2017, 12).



Bay of Ireland macrofossils from Test pit 1 cont. (Sharpe 2014, 40; Timpany et al. 12).

range of their ‘macroscopic’ charcoal, they simply classified it as >1mm. The current macrofossil investigation also recovered ‘macroscopic’ charcoal fragments, but all measuring <3mm, which places it at the small end of ‘macroscopic.’ These fragments were only just visible to the naked eye and, in relative terms, still considered miniscule despite the anthracological classification as ‘macroscopic’ (Scott and Damblon 2010, 2).

Different interpretations of miniscule charcoal remains are not uncommon among palaeoenvironmentalists, as the subject continues to be a contentious area of debate among scholars (Bishop et al. 2015, 51). Given the ambiguity of such remains, however, attempting to determine a definite cause and source of origin for charcoal assemblages proves near impossible (Tipping 1994, 16; Tipping 2004, 48). For example, the presence of charcoal particles simply denotes burning of plant material, but does not indicate whether the cause of this burning was natural or deliberate (Edwards and Ralston 1984, 25; Edwards and Whittington 2000, 79). While Mesolithic communities may have purposely burned vegetation as a hunting or plant cultivation strategy, fires also occurred due to natural causes, such as lightning strikes (Edwards and Whittington 2000, 79). Both instances of burning produce identical charcoal assemblages, preventing a determination of their cause. Moreover, Mesolithic people also created fires for many reasons, including heating and cooking purposes (Bishop et al. 2015, 68; Brown 1997, 135; Edwards 1990, 76; Edwards and Ralston 1984, 25; Edwards and Whittington 2000, 79). The charcoal produced from these fires also resembles the charcoal produced by the natural or deliberate burning of vegetation. Given the proximity of the site to the coast and the affinity of late-Mesolithic communities for coastal settlement, it is probable that domestic fires occurred in the area. Even if a local settlement did not exist, the stormy weather could have transported miniscule charcoal particles via the wind or the sea from nearby areas of known burning activity, such as the island of Hoy (Figure 5.9) (Timpany et al. 2017, 17), or nearby areas of human activity, such as the Loch of Stenness. Hence, determining a source for miniscule charcoal remains also proves highly problematic.

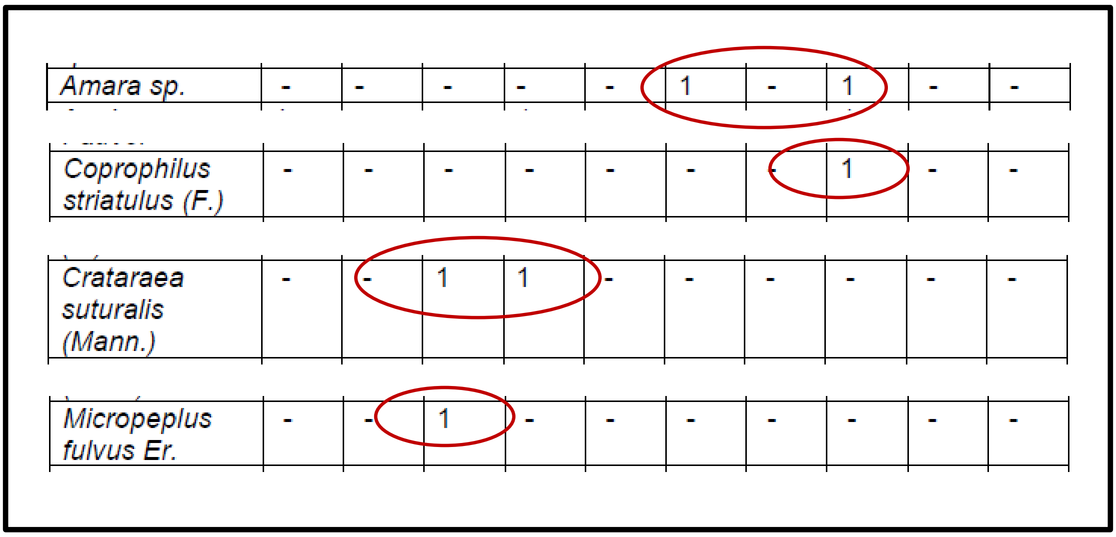
Thus, attributing the presence of miniscule charcoal particles to the deliberate burning of the reedswamp by Mesolithic people as a means of managing the vegetation makes several unfounded assumptions regarding these remains, not least of which pertains to *in situ* burning. In fact, given that neither investigation recovered any charred plant fossils, the charcoal assemblages likely do not represent a primary deposit (Scott et al. 2000, 19-20). Therefore, as a secondary deposit, some factor of taphonomy is inevitably responsible for the presence of this charcoal (Henkel 2018, 2-4) and stormy weather would have readily facilitated either its wind or water transport to the site.

Figure 5.9: Image showing proximity of the site (foreground) to the Island of Hoy (background) (Photograph by Dr. M.H. Field).

Buhat (2018, 36 & 39), on the other hand, interpreted anthropogenic activity at the Bay of Ireland based on the presence of beetle taxa associated with humans. She reports the recovery of 4 different ‘typical synanthropes’, including *Coprophilus striatulus*, *Amara sp.*, *Crataraea suturalis*, and *Micropeplus fulvus* (Figure 5.10) (Buhat 2018, 36 & 39). Only 6 fragments of these beetles, however, were discovered within an assemblage of more than 700 total remains (Figure 5.11). These results do not seem like strong evidence for significant human activity at the site, leaving one to wonder whether, like ‘synanthropic’ plant taxa, these beetles became associated with humans due to anthropogenic facilitation of their habitat niche. If so, then these beetles may have been present at the site due to the natural occurrence of their habitat preference, rather than human activity.

Finally, all three investigations at the Bay of Ireland also suggest possible animal grazing. Timpany et al. (2017) and Buhat (2018 , 36-40) however, obtained more concrete evidence for this activity than the current macrofossil investigation. Timpany et al. (2018, 13) recovered non-pollen palynomorphs indicative of animal dung and animal hairs, while Buhat (2018, 36-40) recovered various beetle taxa indicative of both animal dung and animal grazing. The current macrofossil analysis, on the other hand, only recovered a few seeds from plant taxa sometimes associated with the presence of animals: *Urtica dioica*, which is often associated with animal dung (Stace 1997, 117), and *Ranunculus*, which can be associated with animal grazing (Davidson et al. 1976, 353-354; Farrell 2105 476). The difference in the quality of this evidence may reflect the sensitivity of each palaeoenvironmental proxy for detecting the presence of animals.

Figure 5.10: Fragment of the 'synanthropic' beetle *Micropeplus fulvus* (Buhat 2018, 33).



Amara sp.	-	-	-	-	-	1	-	1	-	-
Coprophilus striatulus (F.)	-	-	-	-	-	-	-	1	-	-
Crataraea suturalis (Mann.)	-	-	1	1	-	-	-	-	-	-
Micropeplus fulvus Er.	-	-	1	-	-	-	-	-	-	-

Figure 5.11: 'Synanthropic' beetle taxa remains for the Bay of Ireland (after Buhat 2018, 41-43).

On the whole, these three investigations agree fairly well with one another, all concluding that the Bay of Ireland comprised a coastal wetland during Orkney's early prehistory. While a degree of variance exists among interpretations, the investigations also appear to complement each other, proving the benefit of employing different palaeoenvironmental proxies in the reconstruction of past environments.

5.5 COMPARISON WITH OTHER ORCADIAN PALAEOENVIRONMENTAL RESEARCH

The prehistoric vegetational ecology observed at the Bay of Ireland fits well within the findings from the wider body of Orcadian palaeoenvironmental research. The dominance of tall herbaceous taxa and the presence of a woodland canopy with fern understory comprise floristic elements commonly reported among analyses of Mid-Holocene sequences (Bunting 1994, 777; Bunting 1996, 198 &203; de la Vega-Leinert et al. 2000, 523; de la Vega-Leinert et al. 2007, 766; de la Vega-Leinert et al. 2012, 133-136; Donaldson 1986, 10-11; Farrell 2015, 472; Keatinge and Dickson 1979, 599;). Furthermore, the recovery of birch fruits agrees with previous descriptions of the prehistoric Orcadian woodland, which all cite *Betula* as the main tree taxa component (Bunting 1994, 777; Bunting 1996, 203; de la Vega-Leinart et al. 2000, 523; de la Vega-Leinert et al. 2007, 767; de la Vega-Leinert et al. 2012, 133; Donaldson 1986, 10; Farrell et al. 2014, 227-230; Farrell 2015, 479; Keatinge and Dickson 179, 602; Moar 1969, 207; Timpany et al. 2017, 14; Whittington et al. 2015, 116-117). Finally, while different fern types have been identified at different sites (Donaldson 1986, 11; Keatinge and Dickson 1979, 602), de la Vega-Leinert (2000, 515) also report the presence of *Dryopteris*-type ferns as part of the local flora community.

More specifically, similar wetland environments to that observed at the Bay of Ireland have been recorded by de la Vega-Leinert et al. (2000, 2007 & 2012) around Mainland Orkney (Figure 5.12). All three of these investigations recovered evidence for Mid-Holocene coastal waterbodies. Their locations, like that of the Bay of Ireland site, lie along the shorelines of various bays, where previous glacier activity created topographical depressions and deposits of glacial till that facilitate the development of ponded wetland (de la Vega-Leinert et al. 2000, 521-523).

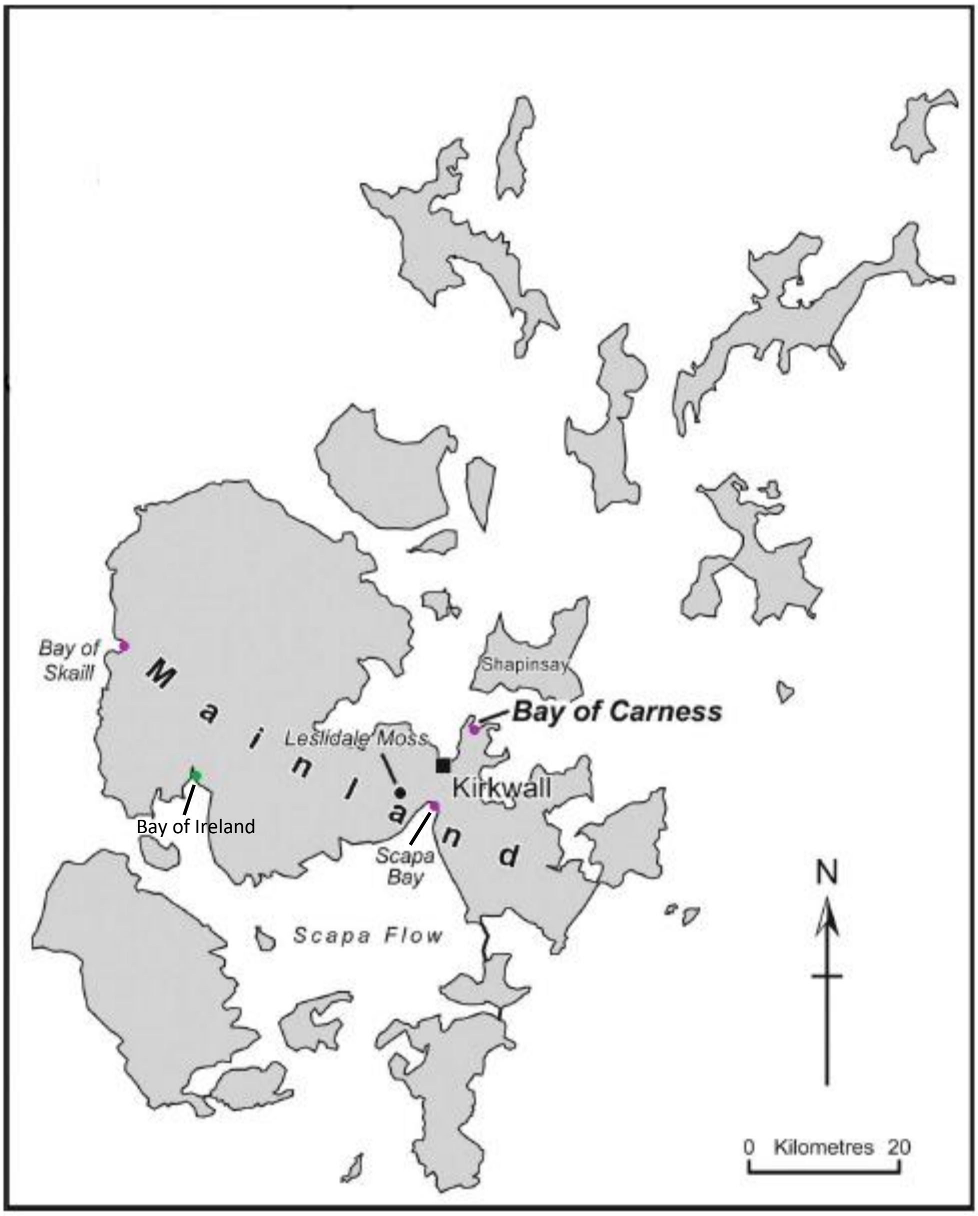


Figure 5.12: Map of other prehistoric coastal wetlands on Mainland Orkney (after de la Vage-Leinert et al. 2012, 120).

At the Bay of Skaill, a fresh waterbody formed in a glacial depression during the Mesolithic period as the local water-table rose in response to rising sea-levels (de la Vega-Leinert et al. 2000, 523). A period of increased sand deposition then decreased the wetland's water depth and transformed its vegetation (de la Vega-Leinert et al. 2000, 515). Pooled water eventually reoccurred as a result of continued sea-level rise (de la Vega-Leinert et al. 2000, 515). These same three wetland phases transpired at the Bay of Ireland and are represented at both sites by the same evidence – the presence, absence and then reappearance of Potamogetonaceae (de la Vega-Leinert et al. 2000, 515). On the whole, these two sites appear very similar. Their biggest difference, however, lies with the varying conditions of the initial waterbodies – fresh versus brackish water. Unlike the Bay of Ireland, no halophytic plant taxa were recovered from the sequence at the Bay of Skaill, indicating a terrestrial water source for the formation of this wetland (de la Vega et al. 2000, 523).

The other two coastal wetland sites, however, feature waterbodies subject to marine influence. At Scapa Bay, a shallow lagoon developed in an area of low-lying land (de la Vega-Leinert et al. 2007, 765). This ponded water formed as a result of rising sea-levels, which caused a local increase in terrestrial freshwater input and tidal flooding (de la Vega et al. 2007, 765-767). The combination of these two contributing water sources created brackish conditions within the standing water of the wetland (de la Vega-Leinert et al. 2007, 765). A later reduction in marine contribution to the lagoon was inferred from decreased values of plant taxa associated with the presence of salt (de la Vega-Leinert et al. 2007, 766). By the Neolithic period, the salinity level of the water had completely disappeared, rendering it a freshwater lagoon featuring plant taxa such as *Potamogeton* sp., *Ranunculus* sp. and *Mentha* sp. (de la Vega-Leinert et al. 2007, 766). Likewise, tidal inundation due to Mid-Holocene sea-level rise created a saltmarsh in a glacial depression at the Bay of Carness (de la Vage-Leinert et al. 2012, 141-143). This waterbody also transformed into a freshwater lagoon after the formation of a costal barrier prevented further marine contribution to its water content (de la Vega-Leinet et al. 2012, 143). The analysis of plant macrofossil remains helped identify the ecological succession at this site, with the recovery of *Ruppia maritima* clearly indicating the presence of brackish water (de la Vega-Leinert et al. 2012, 136-137). Significantly, neither of these two coastal wetlands indicated any anthropogenic influence on the local vegetation until increased human activity in the Neolithic period (de la Vega et al. 2007, 770; de la Vega-Leinert et al. 2012, 143-144).

The coastal wetland at the Bay of Ireland clearly shares common features with all three of these other sites. For example, they all formed in glacial depressions during the Mesolithic period in direct relation to rising sea-levels. They also supported similar floristic communities. Nevertheless, the ecological succession exhibited at the Bay of Ireland most resembles the wetland evolution described for Scapa Bay and the Bay of Carness. At these sites, the formation of coastal barriers, due to the displacement of unconsolidated sediments by wave action, initiated wetland transformation from brackish to freshwater conditions (Figure 5.13) (de la

Vega-Leinert et al. 2012, 121). Thus, it seems that the high-energy maritime climate of Orkney combined with its glacial legacy made costal lagoons not only a prevalent feature of the current landscape (de la Vega-Leinert et al. 2012, 121), but also a common feature of the prehistoric environment.

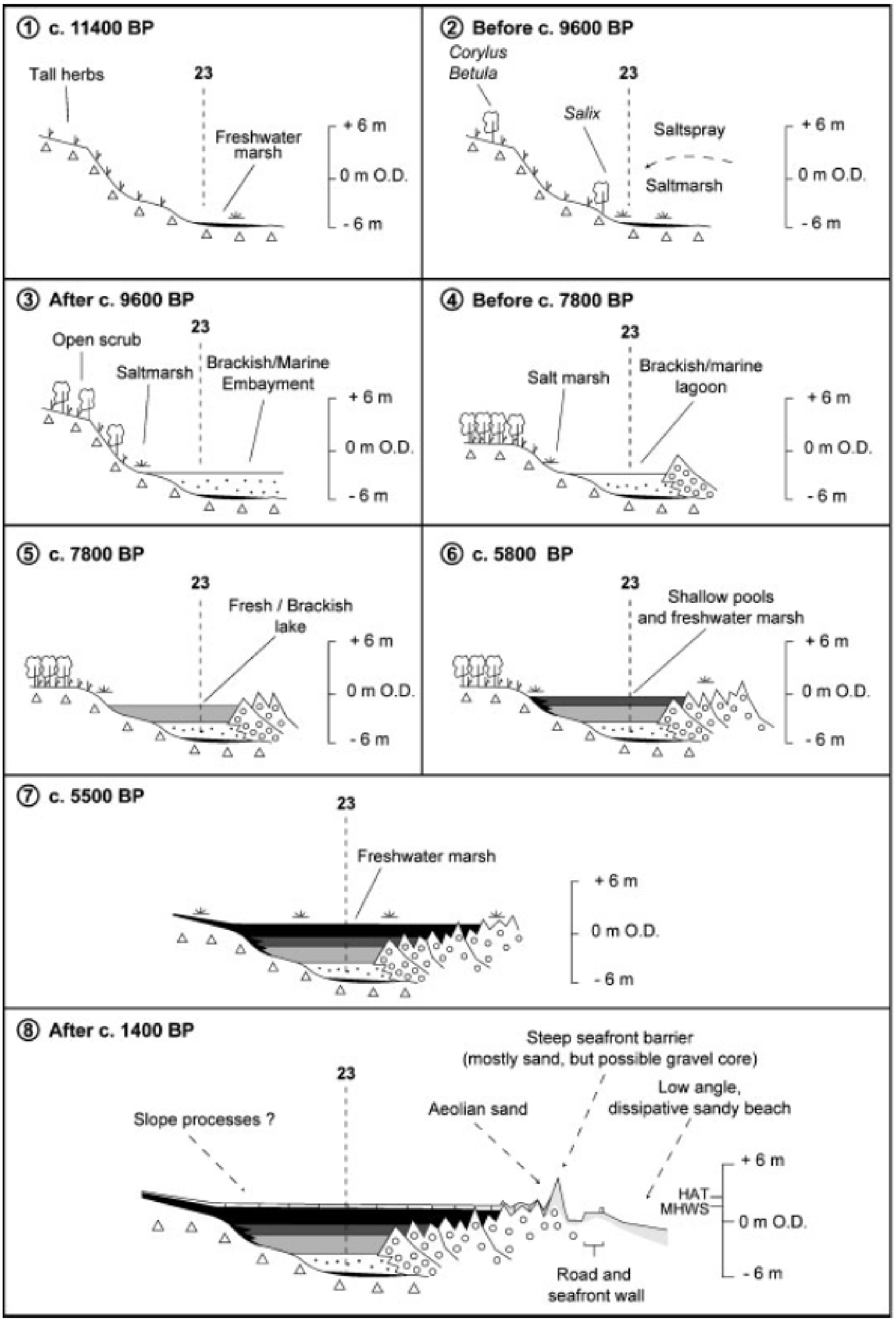


Figure 5.13: Coastal morphology responsible for wetland succession at Scapa Bay (de la Vega-Leinert et al. 2007, 768). Similar process interpreted for the Bay of Ireland.

Chapter 6: Conclusion

This thesis presents the results of a plant macrofossil analysis of late Mesolithic – early Neolithic sediment horizons from a submerged forest site at the Bay of Ireland. The main aim was to create an early prehistoric palaeoenvironmental reconstruction of the site. Specific research objective connected to this work included:

- Determining the vegetational ecology of the immediate area
- Investigating the local presence of tree taxa.
- Identifying changes in vegetation composition over time.
- Discerning potential cause(s) for vegetation succession, such autogenic, climatic, or anthropogenic factors.
- Assessing the quality of the macrofossil data via comparison with previous palynological investigations of Orkney's palaeoenvironment.

Conclusions relating to these research objectives are discussed in section 6.1; while section 6.2 reviews the implications of this study and offers potential lines of investigation for future work.

6.1 ASPECTS OF THE LOCAL PREHISTORIC ENVIRONMENT

The macrofossil data revealed the presence of a coastal wetland at the Bay of Ireland. The vegetational ecology suggested that this wetland comprised a tidal saltmarsh during the late Mesolithic period. Changes in taxa concentrations and distributions over time indicated that the wetland underwent a gradual ecological transformation that culminated in the presence of a partially wooded freshwater fen by the early Neolithic period. Trees featured as part of the marginal vegetation of the wetland, forming peripheral woodland along the landward edge of the marsh. Both *Betula* and *Salix* grew within this tree stand, though – due to taphonomic reasons – other taxa may have also been present that were not represented among the fossil assemblage. As the brackish water conditions of the marsh slowly disappeared, these trees began to encroach further into the wetland, until they formed part of the later fen community.

Bedrock depressions and deposits of glacial till left over from Orkney's glacial legacy facilitated the development of a coastal wetland at the site by creating an area of low-lying land with poor water-drainage abilities. Increased sea-level rise periodically inundated the depression during extremely high tides and elevated wave action due to stormy weather. Around the time of the Mesolithic-Neolithic transition, a barrier was created that severed the saltmarsh's connection to the sea. As a result, the hydrology of the wetland changed. Marine influence no longer served as its primary water source. Instead, ground seepage – from a high water-table related to continued sea level rise – and precipitation acted as the main feeds for the wetland, diluting the former salinity levels of its waters and altering its vegetational ecology.

Since no definite signs of human activity were inferred from the macrofossil evidence, anthropogenic influence is unlikely to have caused the hydrological change that resulted in vegetation succession at the site. Climatic factors seem far more probable as the cause for this floristic evolution. As discerned by de la Vega-Leinert et al. (2000, 2007 & 2012), a period of prolonged gales and storms around this time probably displaced unconsolidated sediments, forming a sand barrier across the coastal depression. Bay of Ireland coleoptera remains for this time period lend support to this interpretation with evidence for the presence of sandy terrain (Buhat 2018, 36-37). The fact that three other early prehistoric wetland sites also demonstrate a similar vegetational succession due to a change in hydrology, attests to a regional cause, such as stormy weather, rather than local autogenic or anthropogenic factors. Severe Orcadian weather conditions, may also explain the switch from timber construction to stone architecture observed in the archaeological record, as well as the widespread occurrence of subterranean dwellings (Ottaway and Holton-Krayenbuhl 2009, 60). Thus, unlike other investigations at the Bay of Ireland that interpret anthropogenic influence on the local flora, this investigation concludes that climatic factors, rather than human-plant interactions, played a more significant role in determining the prehistoric vegetational ecology at the site.

Overall, the present investigation has demonstrated the complimentary value of macrofossil analysis to pollen-dominated palaeoenvironmental research. Plant macrofossils provide a more local signal than palynology may be able to perceive, thus producing more details concerning aspects of the immediate environment and its vegetational ecology. While this investigation would have benefitted from a slightly higher analytical resolution, it still succeeded at providing a fairly descriptive palaeoenvironmental reconstruction for the Bay of Ireland.

6.2 IMPLICATIONS AND FUTURE WORK

Over the course of this thesis research, it became apparent that Orcadian palaeoenvironmental interpretations demonstrate a degree of anthropocentricism – no doubt influence by the archaeological fame of the archipelago and its remains. Recent work by Farrell et al (2014) has called attention to this issue, but the contrasting interpretations for human activity at the Bay of Ireland, suggests the possible continuance of this trend. There is, however, the possibility that a macrofossil analysis may not be as sensitive at detecting anthropogenic indicators as other palaeoenvironmental proxies and future research should investigate this potential difference.

Comparison with previous Orcadian palaeoenvironmental investigations, however, reveals that the macrofossil-based reconstruction of the prehistoric environment at the Bay of Ireland agrees with studies from other bays around Mainland Orkney. Three sites, The Bay of Skaill, Scapa Bay and The Bay of Carness, featured coastal wetlands during early Orcadian prehistory, two of which also exhibited vegetational ecologies indicative of saltmarshes that later became fresh waterbodies due to the same process of coastal morphology as interpreted at the Bay of Ireland (de la Vega-Leinert et al. 2000, 2007 & 2012). Interestingly, like this macrofossil investigation, neither of the other two saltmarsh sites provided any evidence of late-Mesolithic human activity (de la Vega et al. 2007, 770; de la Vega-Leinert et al. 2012, 143-144). Recent archaeological discoveries have firmly established early prehistoric occupation of the island, so the lack of local anthropogenic influence does not relate to a lack of human presence. This absence of human activity could imply that saltmarshes did not constitute important areas of exploitation for early prehistoric communities. A decrease in shade tolerant plant taxa at the Bay of Ireland indicated an opening up of the woodland canopy, a factor which could relate to late Mesolithic and early Neolithic tree exploitation for structural timbers and firewood. This activity, however, only involved the marginal woodland at the wetland and did not appear to affect the vegetation of the saltmarsh itself.

In conclusion, coastal wetlands appear to comprise a type of common ground within Orkney's prehistoric landscape. More palaeoenvironmental investigations are needed to explore whether this landscape feature was restricted to the Mainland or also occurred on other Orcadian islands, and to resolutely determine the extent to which these environments factored into the plant exploitation practices of Orkney's early prehistoric settlers.

Abstract

This thesis research involves a macrofossil analysis of late Mesolithic – early Neolithic sediment horizons from the rare remains of a submerged forest site at the Bay of Ireland on west-Mainland Orkney. It serves as part of a wider, multidisciplinary investigation of Orkney's early prehistoric environment. The results of the analysis facilitated a palaeoenvironmental reconstruction that indicated the presence of a late Mesolithic tidal saltmarsh. The data also suggested that, due to Orkney's prevalent stormy weather, the formation of a coastal barrier initiated the saltmarsh's evolution into a freshwater wetland. By the early Neolithic, the site consisted of a partially wooded fen. Throughout this process human activity does not appear to have affected the local vegetation, though some animal grazing may have occurred.

Comparison with other Orcadian palaeoenvironmental work revealed this vegetational ecology and succession to be a recurrent feature of Orkney's early prehistoric environment. Three investigations conducted at other bays around the Mainland also described similar floristic communities that underwent comparable transformations due to the same process of coastal morphology. Significantly, two of these sites, like the Bay of Ireland, did not indicate any anthropogenic influence on the vegetation until after the onset of the Neolithic period. The results of this thesis research tentatively suggest that while saltmarshes may have comprised a type of common ground within the early prehistoric Orcadian landscape, they did not constitute important exploitation environments to the first settlers of the Orkney Isles. Future research is recommended to test this hypothesis.

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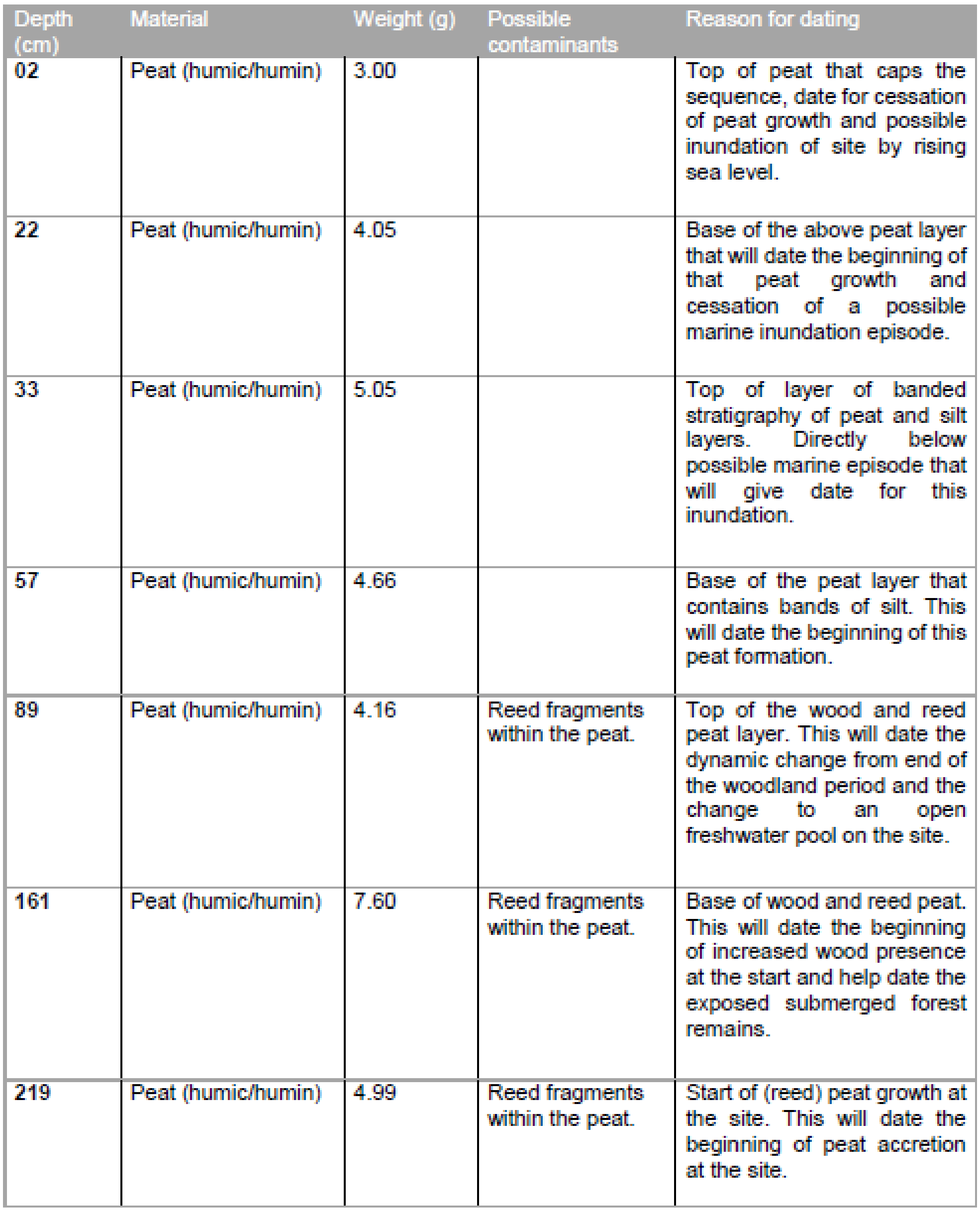
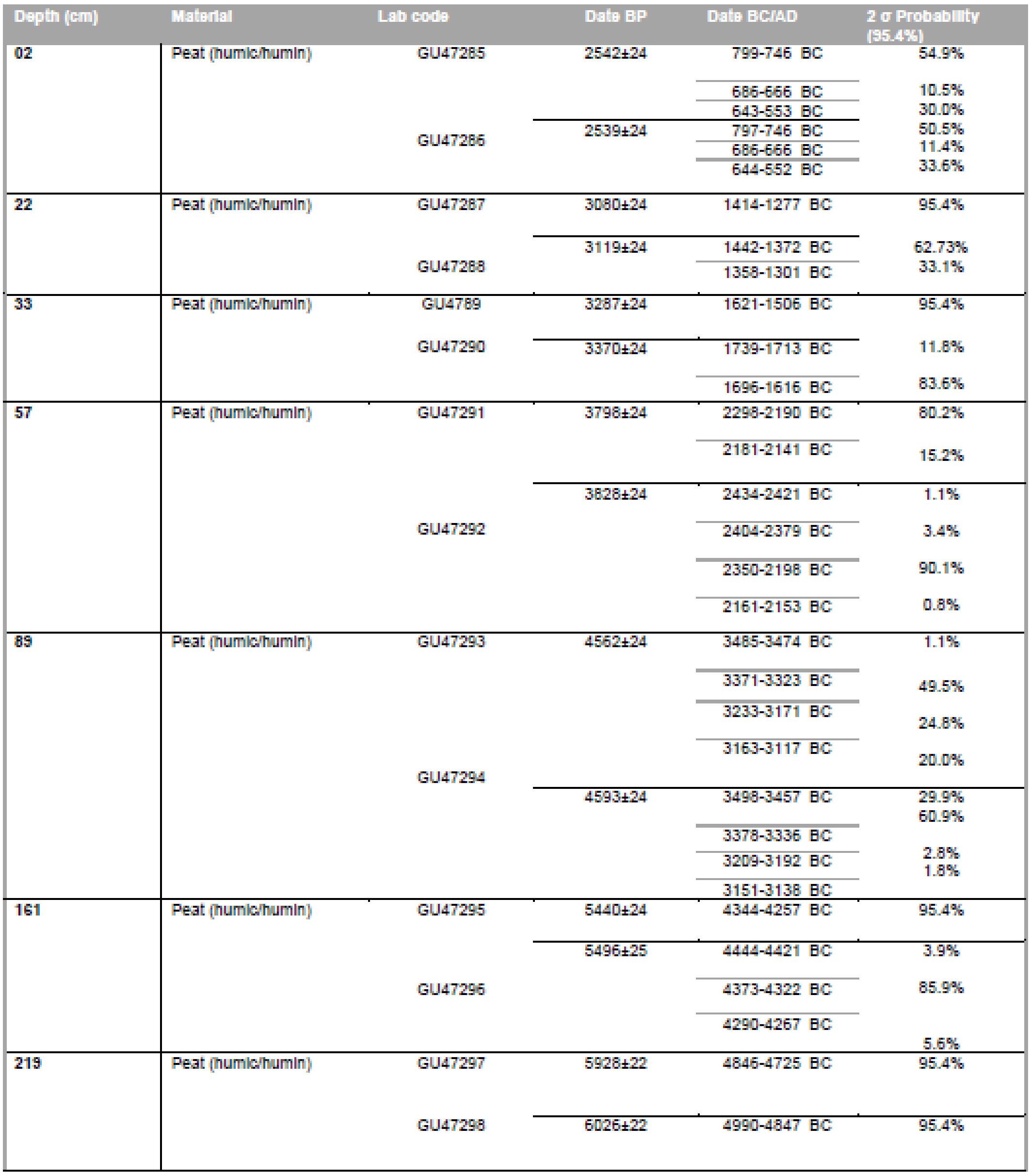
Appendix 1: Description of radiocarbon samples (Buhat 2018, 71).



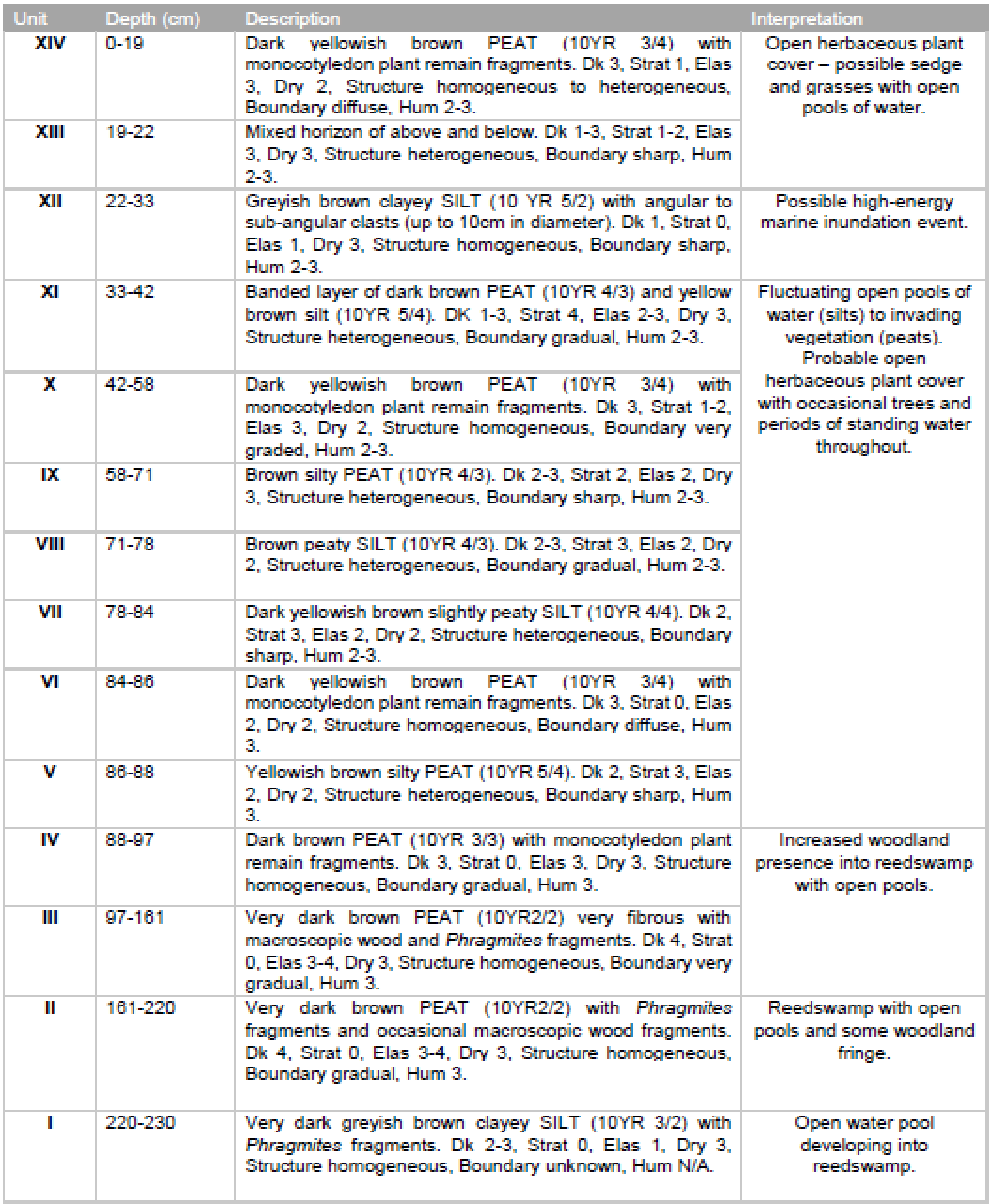
Depth (cm)	Material	Weight (g)	Possible contaminants	Reason for dating
02	Peat (humic/humin)	3.00		Top of peat that caps the sequence, date for cessation of peat growth and possible inundation of site by rising sea level.
22	Peat (humic/humin)	4.05		Base of the above peat layer that will date the beginning of that peat growth and cessation of a possible marine inundation episode.
33	Peat (humic/humin)	5.05		Top of layer of banded stratigraphy of peat and silt layers. Directly below possible marine episode that will give date for this inundation.
57	Peat (humic/humin)	4.66		Base of the peat layer that contains bands of silt. This will date the beginning of this peat formation.
89	Peat (humic/humin)	4.16	Reed fragments within the peat.	Top of the wood and reed peat layer. This will date the dynamic change from end of the woodland period and the change to an open freshwater pool on the site.
161	Peat (humic/humin)	7.60	Reed fragments within the peat.	Base of wood and reed peat. This will date the beginning of increased wood presence at the start and help date the exposed submerged forest remains.
219	Peat (humic/humin)	4.99	Reed fragments within the peat.	Start of (reed) peat growth at the site. This will date the beginning of peat accretion at the site.

Appendix 2: Test pit 2 radiocarbon results (Buhat 2018, 72).



Depth (cm)	Material	Lab code	Date BP	Date BC/AD	2 σ Probability (95.4%)
02	Peat (humic/humin)	GU47285	2542±24	799-746 BC	54.9%
				686-666 BC	10.5%
				643-553 BC	30.0%
		GU47286	2539±24	797-746 BC	50.5%
				686-666 BC	11.4%
				644-552 BC	33.6%
22	Peat (humic/humin)	GU47287	3080±24	1414-1277 BC	95.4%
		GU47288	3119±24	1442-1372 BC	62.73%
				1358-1301 BC	33.1%
33	Peat (humic/humin)	GU4789	3287±24	1621-1506 BC	95.4%
		GU47290	3370±24	1739-1713 BC	11.8%
				1696-1616 BC	83.6%
57	Peat (humic/humin)	GU47291	3798±24	2298-2190 BC	80.2%
				2181-2141 BC	15.2%
		GU47292	3828±24	2434-2421 BC	1.1%
				2404-2379 BC	3.4%
				2350-2198 BC	90.1%
				2161-2153 BC	0.8%
89	Peat (humic/humin)	GU47293	4562±24	3485-3474 BC	1.1%
				3371-3323 BC	49.5%
				3233-3171 BC	24.8%
				3163-3117 BC	20.0%
		GU47294	4593±24	3498-3457 BC	29.9%
				3378-3336 BC	60.9%
				3209-3192 BC	2.8%
				3151-3138 BC	1.8%
161	Peat (humic/humin)	GU47295	5440±24	4344-4257 BC	95.4%
		GU47296	5496±25	4444-4421 BC	3.9%
				4373-4322 BC	85.9%
				4290-4267 BC	5.6%
219	Peat (humic/humin)	GU47297	5928±22	4846-4725 BC	95.4%
		GU47298	6026±22	4990-4847 BC	95.4%

Appendix 3: Stratigraphic sequence and interpretations for Test pit 2 (courtesy of Scott Timpany).



Unit	Depth (cm)	Description	Interpretation
XIV	0-19	Dark yellowish brown PEAT (10YR 3/4) with monocotyledon plant remain fragments. Dk 3, Strat 1, Elas 3, Dry 2, Structure homogeneous to heterogeneous, Boundary diffuse, Hum 2-3.	Open herbaceous plant cover – possible sedge and grasses with open pools of water.
XIII	19-22	Mixed horizon of above and below. Dk 1-3, Strat 1-2, Elas 3, Dry 3, Structure heterogeneous, Boundary sharp, Hum 2-3.	
XII	22-33	Greyish brown clayey SILT (10 YR 5/2) with angular to sub-angular clasts (up to 10cm in diameter). Dk 1, Strat 0, Elas 1, Dry 3, Structure homogeneous, Boundary sharp, Hum 2-3.	Possible high-energy marine inundation event.
XI	33-42	Banded layer of dark brown PEAT (10YR 4/3) and yellow brown silt (10YR 5/4). DK 1-3, Strat 4, Elas 2-3, Dry 3, Structure heterogeneous, Boundary gradual, Hum 2-3.	Fluctuating open pools of water (silts) to invading vegetation (peats). Probable open herbaceous plant cover with occasional trees and periods of standing water throughout.
X	42-58	Dark yellowish brown PEAT (10YR 3/4) with monocotyledon plant remain fragments. Dk 3, Strat 1-2, Elas 3, Dry 2, Structure homogeneous, Boundary very graded, Hum 2-3.	
IX	58-71	Brown silty PEAT (10YR 4/3). Dk 2-3, Strat 2, Elas 2, Dry 3, Structure heterogeneous, Boundary sharp, Hum 2-3.	
VIII	71-78	Brown peaty SILT (10YR 4/3). Dk 2-3, Strat 3, Elas 2, Dry 2, Structure heterogeneous, Boundary gradual, Hum 2-3.	
VII	78-84	Dark yellowish brown slightly peaty SILT (10YR 4/4). Dk 2, Strat 3, Elas 2, Dry 2, Structure heterogeneous, Boundary sharp, Hum 2-3.	
VI	84-86	Dark yellowish brown PEAT (10YR 3/4) with monocotyledon plant remain fragments. Dk 3, Strat 0, Elas 2, Dry 2, Structure homogeneous, Boundary diffuse, Hum 3.	
V	86-88	Yellowish brown silty PEAT (10YR 5/4). Dk 2, Strat 3, Elas 2, Dry 2, Structure heterogeneous, Boundary sharp, Hum 3.	
IV	88-97	Dark brown PEAT (10YR 3/3) with monocotyledon plant remain fragments. Dk 3, Strat 0, Elas 3, Dry 3, Structure homogeneous, Boundary gradual, Hum 3.	Increased woodland presence into reedswamp with open pools.
III	97-161	Very dark brown PEAT (10YR2/2) very fibrous with macroscopic wood and *Phragmites* fragments. Dk 4, Strat 0, Elas 3-4, Dry 3, Structure homogeneous, Boundary very gradual, Hum 3.	
II	161-220	Very dark brown PEAT (10YR2/2) with *Phragmites* fragments and occasional macroscopic wood fragments. Dk 4, Strat 0, Elas 3-4, Dry 3, Structure homogeneous, Boundary gradual, Hum 3.	Reedswamp with open pools and some woodland fringe.
I	220-230	Very dark greyish brown clayey SILT (10YR 3/2) with *Phragmites* fragments. Dk 2-3, Strat 0, Elas 1, Dry 3, Structure homogeneous, Boundary unknown, Hum N/A.	Open water pool developing into reedswamp.

Appendix 4: Beetle data from Bay of Ireland coleoptera study (Buhat 2018, 41-43).

SampleDepth (cm)/TAXA	*100-110*	*110-120*	*120-130*	*130-140*	*140-150*	*150-160*	*160-170*	*170-180*	*180-190*	*190-200*
Carabidae indet.	1	-	-	-	-	-	-	-	-	-
Carabus sp.	-	1	-	-	-	-	-	-	-	-
Cychrus caraboides (L.)	-	-	1	-	1	-	-	-	-	-
Leistus sp.	-	-	1	-	-	-	-	-	-	-
Elaphrus lapponicus Gyll.	-	-	-	-	-	1	-	-	-	-
Elaphrus riparius (L.)	-	-	-	-	1	-	-	-	-	-
Bembidion properans (Steph.)	-	-	7	8	1	-	-	1	-	-
Bembidion guttula (F.)	-	-	-	-	-	-	-	-	1	-
Bembidion sp.	-	-	-	5	12	7	1	2	-	2
Pterostichus strenuus (Panz.)	-	2	2	-	3	-	-	3	-	-
Pterostichus minor (Gyll.)	-	2	12	5	2	-	2	1	-	1
Pterostichus melanarius (Ill.)	1	1	3	4	3	1	1	-	-	-
Pterostichus sp.	-	-	-	4	2	3	2	-	1	-
Amara sp.	-	-	-	-	-	1	-	1	-	-
Agabus bipustulatus (L.)	1	-	-	1	-	-	-	1	-	-
Agabus sturmii (Gyll.)	-	-	-	-	-	1	-		-	-
Gyrinus sp.	-	-	-	-	-	-	1	1	-	-
Hydraena sp.	8	2	5	2	1	3	3	4	-	1
Ochthebius sp.	8	2	17	56	18	27	7	23	1	4
Limnebius truncatellus (Thun.)	-	-	-	-	-	1	-	-	-	-
Limnebius aluta Bedel	-	-	-	-	-	-	1	-	-	-
Helophorus brevipalpis Bedel	-	-	-	-	1	-	-	-	-	-

SampleDepth (cm)/TAXA	*100-110*	*110-120*	*120-130*	*130-140*	*140-150*	*150-160*	*160-170*	*170-180*	*180-190*	*190-200*
Coelostoma orbiculare (F.)	1	1	-	-	-	-	-	-	-	-
Cercyon tristis (Ill.)	-	-	4	28	3	5	-	8	-	-
Cercyon convexiusculus Steph.	-	-	8	10	10	1	1	6	1	2
Cercyon analis (Payk.)	-	-	1	2	-	1	-	1	-	-
Cercyon sp.	-	-	21	5	2	4	-	3	-	-
Megasternum obscurum (Marsham)	-	-	27	13	17	4	-	2	-	-
Cryptopleurum minutum (F.)	-	1	1	-	-	-	-	-	-	-
Hydrobius fuscipes (L.)	-	-	-	1	-	-	-	-	-	-
Chaetarthria seminulum (Hbst.)	-	-	-	-	-	-	-	-	1	-
Dendrophilus punctatus (Hbst.)	-	2	-	-	-	-	-	-	-	1
Micropeplus fulvus Er.	-	-	1	-	-	-	-	-	-	-
Phyllodrepa ioptera (Steph.)	-	1	1	-	1	-	-	-	-	-
Omalium sp.	-	-	-	1	1	1	-	1	-	-
Olophrum piceum (Gyll.)	1	-	-	-	1	-	-	-	2	-
Lesteva heeri Fauvel	8	-	20	10	-	4	1	5	-	-
Coprophilus striatulus (F.)	-	-	-	-	-	-	-	1	-	-
Stenus sp.	2	2	4	12	4	8	1	5	-	1
Rugilus orbiculatus (Payk.)	-	-	1	-	1	-	-	1	-	-
Lobrathium multipunctum (Grav.)	1	-	-	-	-	-	-	-	-	-
Lathrobium fulvipenne (Grav.)	-	1	-	-	-	-	-	-	-	-

SampleDepth (cm)/TAXA	*100-110*	*110-120*	*120-130*	*130-140*	*140-150*	*150-160*	*160-170*	*170-180*	*180-190*	*190-200*
Lathrobium brunnipes (F.)	-	1	2	8	-	3	2	1	-	-
Lathrobium (s.l.) sp.	1	-	4	3	1	3	-	-	-	-
Xantholinus tricolor (F.)	-	-	-	-	1	-	-	-	-	-
Xantholinus linearis (Ol.)	-	-	-	4	1	-	1	1	-	-
Xantholinus sp.	1	-	-	1	-	-	-	-	-	-
Philonthus sp.	-	-	7	1	1	-	-	-	-	-
Quedius sp.	2	-	5	3	1	-	-	3	-	-
Tachinus marginellus (F.)	-	-	-	-	-	-	-	1	-	-
Crataraea suturalis (Mann.)	-	-	1	1	-	-	-	-	-	-
Aleochara sp.	1	-	-	-	-	-	-	-	-	-
Aleocharinae indet.	-	-	1		-	-	-	-	-	-
Bryaxis bulbifer (Reich.)	--		-	-	-	-	-	-	-	1
Grynobius planus (F.)	-	-	-	-	-	-	-	-	-	1
Phyllotreta sp.	-	-	-	-	1-	-	-	-	-	-
Longitarsus sp.	-	-	-	-	1	-	-	-	-	-
Curculionidae indet.	-	-	-	-	-	1	-	2	1	-
Apion sp.	-	-	-	-	1	-	-	-	-	-
Polydrusus cervinus (L.)	-	-	-	-	1	-	-	-	-	-
Polydrusus pilosus Gred.	-	-	-	-	-	-	-	1	-	-
Polydrusus sp.	-	-	-	-	-	1	-	-	-	-
Gymnetron sp.	-	-	-	1	-	-		-	-	-
Rhamphus pulicarius (Hbst.)	-	-	-		-	-	-	4	-	-