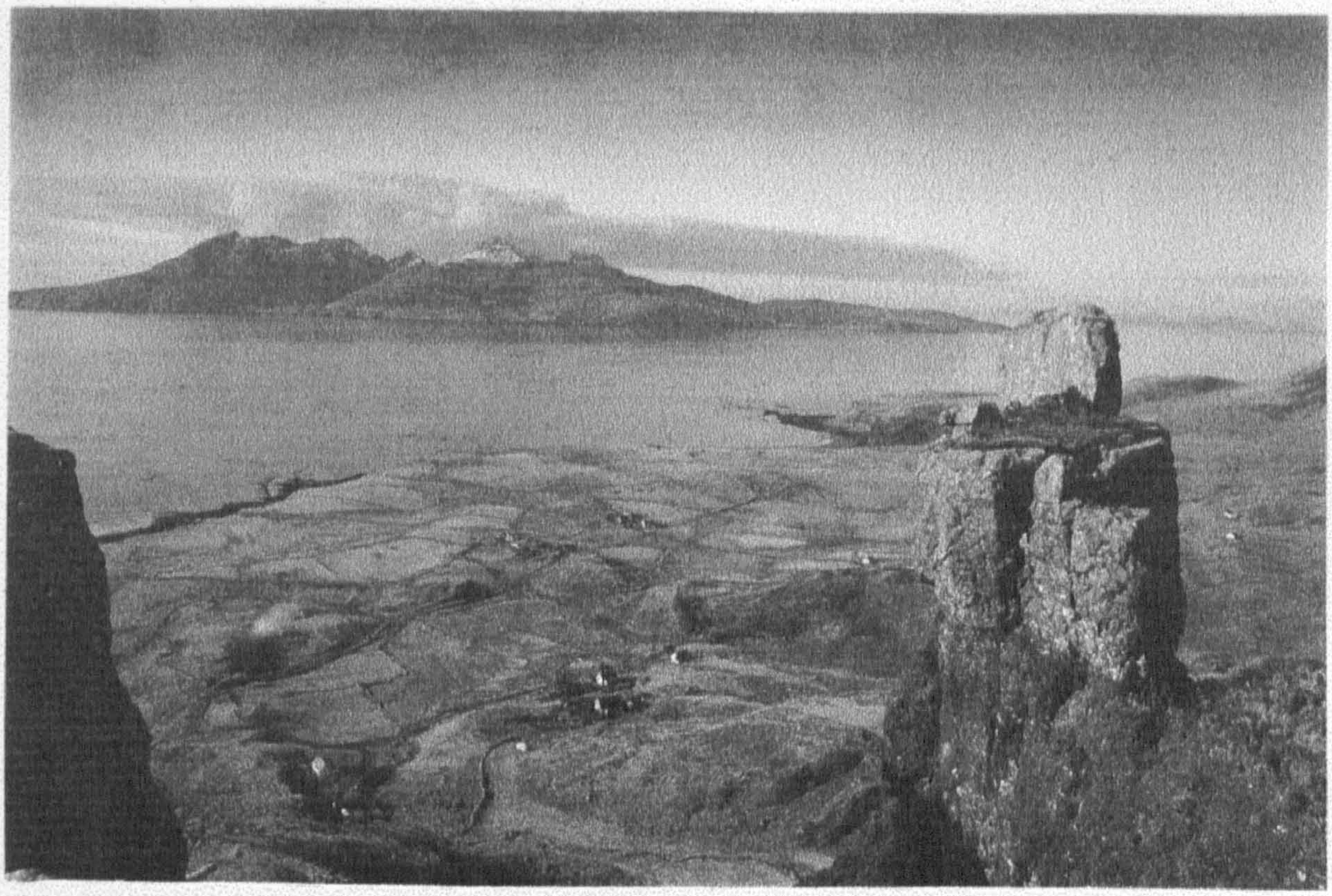
High resolution palynological, multiple profile and radiocarbon dating studies of early human impacts and environmental change in the Inner Hebrides, Scotland

Heather Sugden
Department of Archaeology and Prehistory
University of Sheffield

Thesis submitted for the degree of Ph.D.
December 1999



N'ach rud sōileach a 'drasda n'a b'hanna tighinn a b'habh suib an aite dhuibh bi' phalbh.

"Would it not be a beautiful thing now if you were just coming rather than going"
A traditional Hebridean farewell

VOLUME 1

of 2

ABSTRACT

The Inner Hebrides comprise a diverse range of environments and vegetation, and archaeological evidence suggests that people were interacting with these from early Holocene times. There are relatively few detailed palynological investigations from the islands for the early Holocene and not all the published data include quantification of microscopic charcoal which may assist in the interpretation of human impacts. Radiocarbon dates are also lacking from a number of the published profiles so that inter-site comparisons and comparisons with the archaeological record are difficult.

Some pollen profiles from the Inner Hebrides contain possible indications of human impact in the first half of the Holocene (Lowe and Walker, 1986a; Andrews *et al.*, 1987; Hirons and Edwards, 1990; Edwards and Berridge, 1994). These profiles lack detail however, and it was clear that a multiple profile approach would provide a clearer picture of vegetation change and allow more confident interpretations of the pollen data. The coring of several sites would assist in defining the spatial differences in early Holocene vegetation within the islands and differences in the scale of human impacts which may reflect different types of interference.

Multiple profiles were obtained from Loch a'Bhogaidh (Islay), A'Chrannag bog and Livingstone's Cave bog (Ulva) and Kinloch (Rum), all of which are close to areas of known Mesolithic occupation. A single core was obtained from Loch an t'Suidhe at Bunessan, south west Mull, from where there is currently no archaeological record for the Mesolithic. All cores were analysed for pollen and microscopic charcoal and AMS dates were obtained for all profiles.

The results provide evidence for changes in vegetation due to climatic impacts and inferred Mesolithic activity. The possible effects of human influence vary from temporary woodland reductions to the creation of heathland and cereal cultivation. The use of multiple profiles is validated in that it provides an indication of spatial variation in inferred land use patterns over short timescales. The results are compared with previously published studies and the factors influencing the early Holocene spread of arboreal taxa, and the elm decline, are re-evaluated.

ACKNOWLEDGEMENTS

I am indebted to a large number of people and organisations who have assisted in many ways with the production of this thesis. First and foremost I must thank my supervisor, Prof. Kevin Edwards, for his encouragement, sound advice and resilience in the face of early drafts. Thanks are also due to NERC for my personal funding and for providing the 43 AMS dates used in this project under the supervision of Dr. Charlotte Bryant.

Archie Wood, Scottish Nature, Rum Reserve Trust and the Hon. J. Howard kindly granted access to the coring sites, and assisted with transportation of equipment and cores to and from site. Vic Hughes, Ross Dean, Vicki Vale, Rob Craigie and John Tweddle all assisted with coring, despite the wet and the midges. I would like to thank the islanders for all their hospitality, particularly Marie Kirk, Donald and Scruff from Eigg. Additional thanks must go to Rob Craigie for assistance in the laboratory, to John Tweddle for his comments on my data and ideas, and to Dr. Rex Harland for dinoflaggelate analysis of samples from Ulva. I am also grateful to Prof. Mike Walker and Alan Savile for answering my e-mails and providing informal advice.

I am extremely grateful to all those who provided a baby-sitting service, and to my son Nathaniel, for learning to sleep through the night from an early age and tolerating his mother's long absences. A big thankyou also to Vic Hughes, Neil Wigfield, Rachel and Dave Roebuck, Eibl□s, Neil Oliver, Althea Davies and Ben Hensman, all of whom helped me maintain my sanity through a long and difficult year.

Most of all I must thank my parents for emotional and financial support and my husband Sean for all his support, and for maintaining his sense of humour.

CHAPTER 4 Pollen analysis of sediments from Loch an t'Suidhe, Ross of Mull 105

CHAPTER 5 ULVA. Discussion of multiple profiles from two peat filled basins 120

List of Figures

INTRODUCTION

The Inner Hebrides are located west of the Scottish mainland and consist of numerous islands of diverse geology and topography which were shaped by Tertiary volcanic activity and Quaternary glaciation. Contemporary vegetation ranges from blanket bog communities to mature deciduous woodland, and arctic-alpine plants survive in the mountainous regions on Mull, Rum and Skye. The early Holocene witnessed a rich woodland cover.

Archaeological sites and finds from the islands indicate that humans were inhabiting and utilising the abundance of natural resources throughout the Holocene. The Mesolithic period is particularly well represented on most of the islands, though less so on Mull and Skye, and sites suggesting extensive and prolonged occupation are found at Bolsay, Islay (Mithen and Lake, 1996) and Kinloch, Rum (Wickham-Jones, 1990). Radiocarbon dates on material from Kinloch provide evidence of the earliest known occupation of the islands at 8590±45 BP (7640 cal. BC) (*ibid.*), but it is probable that people were present in the Inner Hebrides much earlier than this (Edwards and Mithen, 1995; Edwards, 1996) as they were in the Scottish mainland (SAN, 1998).

The abundance of Mesolithic archaeology on the islands and the availability of a large number of sites suitable for coring encourage the view that Mesolithic impacts on vegetation are likely to be detected by pollen analysis. Palaeoecological investigations on some of the islands have already been undertaken. The work of Birks (1973), Birks and Williams (1983) and Walker and Lowe (1990; 1991a; 1991b) on Skye, and Lowe and Walker (1986), Walker and Lowe (1985; 1987) on Mull is the most extensive research in the area and focuses especially on the Lateglacial and early Holocene times. Later investigations by Hirons and Edwards (1990) on Rum, Andrews *et al.*,

(1987) on Colonsay, Bennett (1989) and Edwards and Berridge (1994) on Islay were concerned with Holocene vegetation reconstruction within a context of human occupation. Most of these studies suggest reductions in local woodland which may have arisen from the activities of Mesolithic people.

Given the extreme geographical variations of the Inner Hebrides, much greater spatial variation of palynological sites is required in order to fully appreciate the changing patterns of vegetation, including human impacts, throughout the Holocene. It was anticipated that higher resolution pollen sampling would assist in the provision of basic data and allow secure inter-site comparisons, especially if supported by multiple profiles and a sufficient number of radiocarbon dates.

The project

The project aims to detect the impacts of people on early Holocene vegetation in the Inner Hebrides, and to provide more detailed information on changing vegetation patterns in the islands from c. 10,000 BP (9500 cal. BC) covering the Mesolithic at all sites, and the Neolithic and later (from c. 5000 BP [5650 cal BC] onwards) on Rum and Ulva. In order to maximise the potential for detection of small scale vegetation changes multiple profiles from single sites have been used where appropriate.

The main questions addressed in this thesis are as follows:

1. Do multiple coring methods expand greatly on the detail provided by single cores? What are the differences (if any) between profiles from a site and what can be inferred from these in terms of local vegetation composition, sedimentation and pollen distribution and accumulation?

2. Do the pollen records contain evidence of human impact and does this vary between profiles within a site and between sites?

3. How do the early Holocene pollen records from the Inner Hebrides compare with those from the Outer Hebrides and western Scotland?

In order to illuminate the above, several sites were chosen for coring. Loch a'Bhogaidh on Islay and Kinloch on Rum are both located close to areas of known Mesolithic occupation and cores from both suggest temporary woodland reduction during the Mesolithic sites (Edwards and Hirons, 1990; Edwards and Berridge, 1994). A site on Mull was chosen as there is very little evidence of Mesolithic occupation on the island, yet a core from Loch an t'Suidhe (Lowe and Walker, 1986a) displays potential evidence of human activity. Greater sampling resolution and microscopic charcoal quantification was required at this site to assist interpretation. A'Chrannag and Livingstone's Cave bogs on Ulva were chosen due to their proximity to a known site of Mesolithic occupation and the lack of pollen data from the island.

The sites also cover a range of coring environments and incorporate lake sediments and peats. This will allow an assessment of the value of multiple coring methods within different sediments. Implicit in this technique are the requirements of close resolution sampling and AMS dates to allow comparisons, not only of phases of potential human impact, but also of woodland development and vegetation patterns within the islands over thousands of years. This detail may assist in the refinement of isopollen maps for the area and in assessing the degree of impact that Holocene climatic changes may have had.

Structure of the thesis

The thesis is divided into 8 chapters. Chapter 1 provides the geographical background of the Inner Hebrides and summarizes the archaeological evidence and published pollen data from the islands which are to be used as the context for this thesis. Chapter 2 reviews the methods employed in this study and includes commentary on pollen and microscopic charcoal taphonomy in the context of multiple profiles. This is followed by a description of the sites selected for study. The data from each site are presented and discussed in Chapters 3-6. A synthesis of the vegetation reconstructions is included in Chapter 7 in the context of data from other Inner Hebridean sites, as well as sites from the Outer Hebrides and the west coast of Scotland. Chapter 8 comments on the success of the methods employed and makes suggestions for future research.

Conventions and Definitions

Dates

All dates are presented as uncalibrated radiocarbon years before present (BP) to allow comparison with published pollen data. As archaeological publications often refer to calendar years, calibrated dates BC and AD (Stuiver and Reimer, 1993) are included in parentheses within the text for actual and extrapolated dates. Calibration details (Stuiver and Reimer, 1993) of dates on the new profiles in this study are included in Appendix A.

The term Lateglacial refers to the transition period between the last glacial and the current interglacial occurring c. 14,000 - 10,000 BP (14,900 - 9500 cal. BC). The present interglacial (c. 10,000 BP [9500 cal. BC] to the present) is referred to as the Holocene or postglacial.

Nomenclature

Vascular plant nomenclature follows Stace (1991) and pollen and pteridophyte spore nomenclature follows Bennett, 1994. The term 'arboreal' includes both trees and shrubs and the terms 'heath' and 'heathland' refer to dwarf shrubs of the Ericaceae and Empetraceae families.

CHAPTER 1 - GEOGRAPHICAL, ARCHAEOLOGICAL AND PALAEOENVIRONMENTAL BACKGROUND TO THE INNER HEBRIDES, WESTERN SCOTLAND

1.1 Geography of the Inner Hebrides

1.1.1 Climate

The Inner Hebrides (Fig. 1.1) are situated off the western coast of Scotland where the thermal regime has a strong maritime influence from the North Atlantic Drift. Mean annual temperatures are comparable to those in lowland England, but the seasonal range is smaller (Green and Harding, 1983). Mean January minimum and maximum temperatures range between 2°C and 7.5°C , and the range of minimum and maximum temperatures for July is 10.5°C -17°C (Boyd and Boyd, 1990). Islay, the most southerly of the Inner Hebridean islands and the most exposed to maritime influences lies at the warmer end of the scale.

The islands are exposed to east-tracking cyclones and fronts, resulting in frequent and high levels of rainfall which are increased by orographic uplift over the more mountainous islands of Mull (Jermy, 1978), Rum and Skye (Green and Harding, 1983). Rainfall occurs an average of 200 days per year throughout the islands and at least 1mm of rain per day is recorded. Wind speeds are high with an annual range of 15-20 knots and gales are common (*ibid.*).

Although the Inner Hebrides mainly experience cyclonic rainfall (and occasional snow when cyclones are followed by Polar Maritime and Arctic air), the extension of easterly lying anticyclones can bring drier weather (Green and Harding, 1983). A mean maximum for the Inner Hebrides of 20 days per year of snowfall is recorded (Boyd and Boyd, 1990) and snowfall is more frequent and greater on Rum, Mull and Skye than on other islands due to the altitudes of their summits (Green and Harding, 1983; Jermy, 1978).

1.1.2 Geology, Geomorphology and Topography

The solid geology of the Inner Hebridean islands mainly consists of Lewisian Gneiss and Torridonian sandstones (Craig, 1991). Lava floe s from Tertiary volcanic activityoccurredon Skye (Birks, 1973), Mull (Woolley and Jermy, 1978), Eigg and Rum (Wickham-Jones, 1990a); a result of these is Bloodstone Hill (Emeleus, 1987; 1991; Wickham-Jones, 1990a, 1990b) a potential source of material for stone tool manufacture in prehistory (Wickham-Jones, 1990a and b). Tertiary volcanic activity in the Ben More area of Mull also resulted in the high basalt cliffs and columns which are dominant in the coastal landscapes of Mull and the Isle of Ulva (Woolley and Jermy, 1978; Howard and Jones, 1990; Emeleus, 1991).

The landscape of the Inner Hebridean islands has been largely shaped by the climates of the late Devensian glaciation. Following the Devensian cold stage maximum *c.* 18,000 BP (19,450 cal. BC), climatic amelioration reduced the area of ice cover over the islands.

A period of climatic deterioration between c. 11,400 and 10,000 BP (11,430 and 9500 cal. BC) known as the Loch Lomond Stadial (Gray and Lowe, 1973; Ballantyne and Dawson, 1997) may have been preceeded by other readvances in western Scotland (Robinson and Ballantyne, 1979; Dawson, 1982; Peacock, 1983) including the Wester Ross Readvance (Robinson and Ballantyne, 1979). However, the Loch Lomond Readvance is the most recent and clearly defined episode of glacial activity and there is evidence on Skye, Mull and Rum that valley glaciers formed during this time (Peacock, 1983; Price, 1983).

The cold climates of the Loch Lomond Readvance were responsible for the periglacial features, talus, landslips and scree slopes evident in the Inner Hebridean landscapes. Many of these phenomena occur in the mountainous areas such as the Cuillins of Skye, eastern Mull and Rum, where altitudes have exacerbated the climatic effects of the Lateglacial period. Glacial drift and glacimarine sediments also remain exposed (Dawson, 1983), the latter being a source of pebble-washed flint from which prehistoric stone tools have been made (Mercer, 1970, 1974, 1978-80; Wickham-Jones, 1990; Edwards and Berridge, 1994; Edwards and Mithen, 1995).

Climatic change at the end of the Lateglacial and in the early Holocene have also shaped the coastlines of the Inner Hebridean islands and western Scotland. Despite isostatic rebound of the northern landmass, sea levels were temporarily higher than they are today (by as much as 40 m around 13,000 BP [13,870 cal. BC]) (Peacock, 1983; Price, 1983). Subsequent reductions in sea level resulted in the raised beaches which are frequent occurrences with examples in eastern Skye, Jura and south western Rum (Peacock, 1983; Dawson, 1983) and where Lateglacial storm beaches are also found (Peacock, 1983). One of the most important of these features is the Main Lateglacial shoreline which is currently exposed as cliffs in the Oban area of western Scotland and continues sloping under present sea level into the Irish Sea basin (Ballantyne and Dawson, 1997). Many of the caves within the cliff face were occupied by people in the early Holocene (refer to Section 1.3.2).

As climatic amelioration continued from the Lateglacial into the Holocene, glacio-eustatic adjustments resulted in a rise in sea levels, which are thought to have reached a maximum between c. 7200 and 6200 BP (6050 and 5130 cal. BC) (Ballantyne and Dawson, 1997). Isostatic readjustment of the landmasses subsequently produced relatively lower sea levels, and Holocene raised beaches resulting from relative sea level changes are frequent in the coastlines of the Inner Hebrides (Dawson and Dawson, 1994).

Inner Hebridean landscapes are varied due the volcanic origins of much of the geology and the impact of glaciation. Skye (Fig. 1.2) Mull (Fig. 1.3) and Rum (Fig. 1.4) are the most mountainous of the islands with altitudes exceeding 900 m O.D. on Skye and Mull, and 800 m on Rum. Topography is more marked on Rum and its coastline is dominated by steep cliffs. In the south of the island mountain slopes run directly into the sea (cf. McCann and Richards, 1969). Rum is not easily accessible, the easiest routes to the interior being Kinloch Glen which runs east-west and Kilmory Glen which runs north-south. A relatively flat and low-lying area is located to the north west of Rum at Farm Fields where the mouth of the Kinloch River meets Loch Scresort.

Coastal scenery on Skye and Mull varies between cliffs and sandy beaches. The smaller island of Ulva also features basalt cliffs and raised beaches along its coastline, and hills reach a maximum of 313 m O.D. at the summit of Beinn Creagh.

Islay and Jura (Fig. 1.5) are the most southerly of the Inner Hebridean islands. To the north of Islay and on the western peninsula of the Rhinns, the landscape consists of low rolling hills, the highest point on the Rhinns being Beinn Tart a'Mhill at 232m O.D. Southeast Islay is more mountainous, with summits reaching 491 m O.D. in the case of Beinn Bheigeir. Jura is also mountainous, summits typically ranging between 300 and 500 m O.D. and the Paps of Jura reach 785 m. The coastlines of both islands display numerous raised beaches and cliffs and small coves and pebble beaches are also frequent.

1.1.3 Soils

The soils of the Inner Hebrides are fairly uniform due to the similarity of parent materials and the extreme wetness of the climate. Parent materials have been identified as varieties of drift including glacial and morainic tills, raised beaches, aeolian sand and montane frost-shattered detritus. Nine soil classifications have been cited for the islands (Hudson and Henderson, 1983);

1. Brown rendzinas and brown calcareous soils.
2. Brown forest soils.
3. Non-calcareous gleys.
4. Peaty gleys.
5. Humus-iron podzols.
6. Peaty podzols.
7. Organic soils.
8. Montane soils.
9. Regosols.

Rendzinas and brown calcareous soils are confined to the limestones of Skye and Islay. Brown forest soils are derived from Tertiary basalts and occur on

Skye, Mull (Hudson and Henderson, 1983) and the smaller islands including Rum (Jermy *et al.*, 1978) and Colonsay (Birks, 1987).

Peaty gley soils are derived from many drift types and are 'the most extensive soils of the Inner Hebrides' (Hudson and Henderson, 1983: p. 115). Non-calcareous gleys, humus-iron podzols and peaty podzols are also common on all of the islands with humus-iron podzols in particular developing over the sands and gravels of raised beaches. Also common, due to the wetness of climate, are organic soils or peats which are dominated by blanket bog and bog heather moor (Hudson and Henderson, 1983).

Montane soils are categorized by altitude as sub-alpine (over 400 m) and alpine (over 700 m) and alpine soils usually show evidence of active or fossil periglacial activity (Hudson and Henderson, 1983) examples of which are found in the Cuillins of Skye, and on Rum.

Regosols are soils which are immature and developing on unconsolidated material. An example is machair which develops on blown sand (Hudson and Henderson, 1983) and may be seen on Tiree (Peacock, 1983), Mull (Jermy *et al.*, 1978), Oronsay and Colonsay (Birks, 1987). Regosols of unstable colluvium have been noted on Tertiary rocks to the west of Rum (Emeleus, 1987).

1.1.4 Vegetation

The vegetation of the Inner Hebridean islands is closely linked to soils, thus variations on acid-tolerant wetland communities are prevalent. Major classifications are heather moor, bent-fescue bog and bent-rush-fescue grassland although greater detail specific to each island may be found in Birks (1973, Skye), Jermy and Crabbe (1978, Mull), Ball (1987, Rum), Howard and Jones (1990, Ulva), Ogilvie (1995, Islay), and Boyd and Boyd (1990) and Currie and Murray (1983). The altitudes experienced on Rum, Mull and Skye result in pockets of sub-alpine flora which include *Alchemilla alpina* (Alpine Lady's mantle), *Cardaminopsis petraea* (northern rock cress) (Ball, 1987; Bangerter *et al.*, 1978), *Minuartia sedoides* (cyphel) (Currie and Murray, 1983) and only Rum has specimens of *Thlaspi alpestre* (alpine penny-cress) (Currie and Murray, 1983). The islands also have arctic-subarctic elements including *Koenigia islandica* (Iceland purslane) on Rum and Mull (Ball, 1987; Bangerter *et al*, 1978) and *Arenaria norvegica* ssp. *norvegica* (Arctic sandwort) on Rum and Eigg (Currie and Murray, 1983). The exposure experienced on the west coast of Colonsay means that this island also retains similar arctic-alpine refugia (Birks, 1987).

According to paleoenvironmental data, the Inner Hebrides were more widely wooded in the past (Birks, 1983; Ball, 1987; Birks, 1989; Boyd and Boyd, 1990; Tipping, 1994; Edwards and Whittington, 1997), but most of the natural woodland of the islands is now extinct. Ball (1983) states that the current distribution of natural woodland is closely linked to sheltered areas, altitude and soils.

Relicts of natural woodland survive on Rum in steep gullies and this consists of *Betula pubescens* (downy birch) scrub including *Ilex angustifolium* (holly), *Crataegus monogyna* (hawthorn) and *Salix* spp. (willow) (Ball, 1987; Rum Reserve Office, 1996). Since 1957, when Rum became a National Nature Reserve, the north side of Kinloch has been extensively replanted with species including *Alnus glutinosa* (alder), *Corylus avellana* (hazel), *Salix* spp. (willow), *Fraxinus excelsior* (ash), *Ulmus glabra* (wych elm) and *Quercus* spp. (oak). Other planting was undertaken in the Kinloch and Papadil areas by the Bullough family in the last century (Ball, 1987).

Both Colonsay and Skye are well wooded in parts, mainly with *Quercus petraea* and *Corylus avellana*, although *Sorbus aucuparia* (rowan) and *Ilex angustifolium* are also present (Birks, 1973; 1987). The northern natural limit of *Quercus* in the Inner Hebrides occurs in the centre of Skye (Birks, 1973). Some pockets of natural *Betula-Corylus* scrub survive on Islay although there is now almost no native woodland existing on neighbouring Jura (Ball, 1983) and there are small areas of natural woodland on Mull which consist of *Corylus* scrub and *Betula-Quercus* woodland (Jermy, 1978; Ball, 1983). Replanting of mixed woodland in the last century has taken place in the Sorn Valley at Bridgend, Islay (Edwards, pers. comm.) and commercial conifer plantation occurs on the southern Rhinns of Islay and on Jura. Similar plantations dominate the Mishnish area in the north of Mull (Jermy *et al.*, 1978).

The coastlines of the Inner Hebridean islands obviously support maritime plant communities although some montane species may be found on the sea cliffs of Islay, Skye, Mull and Eigg. These include *Saxifraga oppositifolia* (purple saxifrage) and *Silene acaulis* (moss campion) (Currie and Murray, 1983). Salt flats are frequently colonized by salt-tolerant moorland species such as *Molinia caerulea* (purple moor grass) and *Eriophorum angustifolium* (common cottongrass) in addition to halophytic species such as *Armeria maritima* (thrift) and *Plantago maritima* (sea plantain) (Currie and Murray, 1983). Machair grasslands are also found in the Inner Hebridean islands with examples on

Oronsay, western Colonsay (Birks, 1987) and the north coast and Ross of Mull (Jermy *et al.*, 1978).

1.2 Archaeological evidence for early Holocene human occupation in the Inner Hebrides

1.2.1 The Palaeolithic (Fig. 1.6)

For most of the European Upper Palaeolithic period, Scotland was covered in glacial ice. Any archaeological evidence for the occupation of Scotland during interglacial episodes will have been destroyed by subsequent glaciations (Ballantyne and Dawson, 1997) and there is currently no accepted evidence for a Palaeolithic human presence in Scotland. Suggestions have been made by Mercer (1970) that possible tanged points found on Jura are similar to Ahrensburgian-type points which can date to the late Upper Palaeolithic, and he speculates that the ameliorating lateglacial climate and environment of the Inner Hebrides would have been conducive to human occupation. Edwards and Berridge (1995) make similar speculations in the light of palynological and artefactual evidence from the islands.

Other evidence for a Palaeolithic presence in Scotland has come from an assemblage of reindeer antlers from Reindeer Cave, Inchnadamph, Assynt, northwest Scotland. The fragmentation of the antlers was originally interpreted by Movius (1940) as artefactual, the result of human activity. Subsequent radiocarbon dating of a bulked sample of antler fragments provided an age of c.10,080 BP (11,030 cal. BC) for the assemblage and the presence of arctic vole and other lateglacial-type faunal remains from the same context confirmed that the antlers could have been of Upper Palaeolithic origins (Morrison and Bonsall, 1980). However, reinterpretation of the assemblage (Lawson and Bonsall, 1986; Murray *et al.*, 1993) suggested that fragmentation occurred as a result of post-depositional processes and that the antlers were naturally shed.

The remaining evidence for a Palaeolithic presence in Scotland is circumstantial. Following the find of a scraper in a North Sea core which may potentially date to c. 18,000 BP (19,450 cal. BC), Long *et al.* (1986) suggested that evidence of Palaeolithic occupations may now be below sea level, and that coring of submarine sediments may eventually confirm this (cf. Coles, 1998).

1.2.2 The Mesolithic (Fig. 1.6)

The impetus for research into the Scottish Mesolithic has evolved from the work of Lacaille (1954). 'The Stone Age in Scotland' provided a comprehensive environmental background and archaeological summary for the Scottish Mesolithic and is currently the only synthesis of the Mesolithic in Scotland (Morrison, 1996). Many of the sites mentioned by Lacaille (1954) had been investigated by antiquarians of the late 19th and early 20th centuries. These included the middens on Oronsay and caves along raised beach deposits on the west coast of Scotland near Oban. Movius (1940) was one of the early excavators, also with an interest in northern Irish Mesolithic sites, and was the first to use the terms Larnian (for the Irish Mesolithic industries) and Obanian (for the Scottish cave and midden sites), both of which were used by Lacaille (1954). 'Obanian' is now recognised as the term for a Mesolithic industry of western Scotland and the Inner Hebrides, although debate continues as to what exactly comprises an 'Obanian' site or assemblage (Finlayson, 1995; Bonsall, 1996; Finlayson, 1996).

Since Lacaille (1954) there have been major advances in the discovery and research of Mesolithic sites in Scotland, particularly in the last 10-15 years. Developments in the interpretation of site functions and improved dating of Mesolithic deposits have added to the debate on various controversies, such as the date for the earliest human settlement in Scotland, the potentially varying functions of different sites and the provenance of artefactual finds and their significance (Finlayson, 1996).

1.2.1.1 Archaeological sites (Fig. 1.6)

Much of the evidence for the Scottish Mesolithic has come from the west coast of Scotland and the Inner Hebridean islands in particular. The archaeology can be split into two main groups; middens which are frequently associated with caves, and lithic scatters (Fig.1.2). Most cave midden sites are located on the coast of the western mainland near Oban (Lacaille, 1954; Bonsall, 1996), although Livingstone's Cave on Ulva (Bonsall *et al.*, 1991, 1995) is an exception. Open midden sites are located on Oronsay (Lacaille, 1954; Mellars, 1987), and a midden which is currently unexcavated was recently discovered near Dervaig on Mull (Robins, 1998), an island where no substantial Mesolithic archaeological sites were previously known. A few isolated lithic finds from the Aros area of Mull had been ascribed to the Mesolithic by Alan Saville (pers. comm.).

Lithic scatters in the Inner Hebrides have been excavated at Staosnaig on Colonsay and at several places on Islay, including Bolsay Farm and Gleann Mor, as part of the Southern Hebrides Mesolithic Project (Mithen, 1995; Mithen and Lake, 1996). Other excavated lithic sites include Newton on Islay

(McCullagh, 1990), Kinloch on Rum (Wickham-Jones, 1990) and Lealt Bay, Lussa Wood and Glenbatrick Waterhole on Jura (Mercer 1970; 1974; 1978-80). Several other isolated lithic finds have been made on Rum (Wickham-Jones, 1990a; 1990b) and Ulva (Bonsall *et al.*, 1991, 1995).

Most midden sites from both the west coast of Scotland and the Inner Hebridean islands are ascribed to the 'Obanian' tradition. The artefacts associated with 'Obanian' sites are bevel-ended stone tools and bone tools, whilst lithic scatters are typified by narrow blade technology (Finlayson, 1995; Finlayson, 1996). Interpretation of these different artefactual assemblages originally led to the conclusion that the Obanian industry was later in date than the narrow blade industry, and even early Neolithic rather than Mesolithic (Woodman, 1990), but radiocarbon dates suggest that the two industries are contemporary and that their differences may either be a reflection of function (Bonsall and Smith, 1990; Bonsall, 1996) or preservation of material (Finlayson, 1996). However, there remain problems with the allocation of sites to certain industries as some midden sites such as that at Livingstone's Cave, Ulva, have not presented a 'typically Obanian' assemblage of finds (Finlayson, 1995; Finlayson, 1996). Nevertheless, radiocarbon dates and artefactual assemblages secure all Inner Hebridean sites mentioned above and shown in Figure 1.2 within a Mesolithic timescale.

1.2.1.2 Excavations and evidence for resource utilisation

The abundance of Mesolithic sites in the Inner Hebrides is perhaps not surprising in view of the variety of resources which the islands would have been able to provide. The recovery of finds from excavations of the Inner Hebridean sites differs according to the type of site investigated, preservation, and the area of excavation, but overall the finds reflect the diversity of habitats exploited by Mesolithic people.

Palaeoenvironmental data indicate that woodland cover was far greater in the past in the Inner Hebridean islands, consisting mainly of a mixed woodland of birch-hazel-oak (Andrews *et al.*, 1987; Whittington and Edwards, 1997) which would have provided firewood and a variety of foodstuffs. Hazelnuts are abundant on Mesolithic sites and Livingstone's Cave, Ulva and the lithic scatter sites on Colonsay, Jura, Islay and Rum have produced wood charcoal and charred hazel nuts and shells in addition to lithic artefacts (Mercer, 1974; 1978-80; Bonsall, 1989; McCullagh, 1990; Wickham-Jones, 1990b; Mithen and Lake, 1996). Other vegetation types may also have been utilised despite their absence from the archaeological record. These include acorns, elderberries, *Vaccinium* and *Empetrum* berries and the rhizomes of aquatic plants (Price, 1990; Edwards, 1998), all of which were available in the Inner Hebrides.

Prehistoric woodlands would also have supported a wide variety of birds and land mammals including red deer, which are present on most of the Inner Hebridean islands today. Middens on Oronsay and at Livingstone's Cave, Ulva have yielded land mammal remains which provide evidence of hunting, and include red deer antler and pig bone (Grigson and Mellars, 1987; Bonsall, 1989, Russell *et al.*, 1995). Other finds from the midden sites include the bones of marine mammals, fish bones and otoliths, and remnants of shellfish (Mellars, 1987; Bonsall *et al.*, 1989, 1995). Thus Mesolithic people were exploiting marine, coastal and woodland resources at various times in their occupations of the islands.

The stone tools recovered from the Inner Hebridean excavations comprise flints, bloodstone and quartz. Beach-washed flint occurs naturally today on the east coasts of Islay and Colonsay, and to the west of Jura. It is argued that this resource would have been utilised by Mesolithic people (Mercer, 1970; Wickham-Jones, 1990a, 1990b; Edwards and Mithen, 1995), although assuming similar beach conditions then as for the present day, it is debatable whether sufficient nodules would have been available to support the local industries (Mithen, 1995) and it may be that supplies were greater in the past. Bloodstone is likely to have been more abundant than flint in the islands, and although no direct links have been made between bloodstone tools recovered during excavations and potential sources on the islands, Wickham-Jones (1990a, 1990b) suggests that Bloodstone Hill, Rum, is the most likely source of stone for the finds discovered during the excavations at Kinloch.

1.2.1.3 Dates and other evidence

One of the earliest known dates for a Mesolithic presence in Scotland is that from Kinloch, Rum, at 8590±45 BP (7640 cal. BC) (Wickham-Jones, 1990b) although a site near Fife in the east of Scotland has provided a similar date (Wickham-Jones and Dalland, 1998) and a recently excavated site in the Lowther Hills, Clydesdale has provided the oldest date associated with lithics in Scotland so far at 9075±80 BP (c. 8060 cal. BC) (Garavell, 1998; SAN, 1998).

Lithic finds from Mesolithic sites in the British Isles may be ascribed to two main typologies; 'broad blade' assemblages dating to *c.* 9000 BP (8225 cal. BC) and earlier, and 'narrow blade' assemblages which are post *c.* 9000 BP (8225 cal. BC). (Morrison and Bonsall, 1990). Isolated finds of tanged points associated with broad blade technologies have been found in Scotland, including finds from Jura (Mercer, 1978-80), Ballevullin on Tiree (Morrison and Bonsall, 1990) and Newton on Islay (Edwards and Mithen, 1995). The identification of the find from Lussa Bay on Jura as a tanged point (Mercer, 1978-80) has been disputed as the point is severely abraded and broken (Morrison and Bonsall, 1990; Finlayson and Edwards, 1997). There are also problems with the point from Tiree, which was not found in a secure context (Morrison and Bonsall, 1990) and the tanged-type point from Newton, Islay which was found through fieldwalking (Edwards and Mithen, 1995). The lithic assemblage from the excavated site at Newton comprises mainly narrow blade lithics which post-date *c.* 9000 BP (8225 cal. BC) (Edwards and Mithen, 1995) and thus cannot confirm a human presence on Islay prior to this (cf. Finlayson and Edwards, 1997).

Other tanged points in Scotland have been found on the Scottish mainland and Orkney (Morrison and Bonsall, 1990). However, these are also isolated finds, and the only 'broad blade' assemblage representing the early Mesolithic in Scotland comes from Morton, Fife, although radiocarbon dates are possibly later than that for Kinloch at 8050±355 BP (8910 cal. BC) (Coles, 1971).

Thus, there is an abundance of evidence for early human settlement from the Inner Hebrides and west coast of Scotland. Whilst Kinloch on Rum provides the earliest date for human occupation in the islands, it is possible that in the absence of archaeological sites and artefactual evidence, the palaeoenvironmental record may shed additional light on the suggestion that humans were present in the Inner Hebrides prior to *c.* 9000 BP (8225 cal. BC) (Mercer, 1979, 1978-80; Edwards and Mithen, 1995) in addition to contributing to a reconstruction of the environmental background to Mesolithic occupation.

1.2.3 The Neolithic (Fig. 1.7)

Neolithic cultures are generally associated with settled agriculture rather than the hunter-gatherer practices of their predecessors, with a more sedentary existence facilitating the social and practical means of monument building. It may therefore be anticipated that evidence of Neolithic occupations would be greater than for the Mesolithic, as monuments and longer occupation periods of domestic sites are expected to be more durable in the archaeological record. However, known Neolithic sites in the Inner Hebrides are relatively few.

The most common Neolithic remains in the Inner Hebrides are the chambered cairns. Many of these are found on Skye and Islay, although a few examples are located on Colonsay, Jura and Mull (Henshall, 1972; Ashmore, 1996). Stone circles are rare in western Scotland (Ritchie and Harman, 1985), but an exception is Lochbuie stone circle on Mull. Standing stones are also uncommon; a line of standing stones dating to c. 4000 BP (2500 cal. BC) is found at Dervaig on Mull and there are standing stones of supposed similar date at Ballinaby, to the north of Loch Gorm on the Rhinns of Islay.

There is some Neolithic settlement evidence from afore-mentioned Mesolithic sites although this is not extensive. Finds were mostly recovered from small pits and hollows similar to those of the earlier Mesolithic contexts, but blade assemblages and pottery shards suggest Neolithic origins and these have been confirmed by radiocarbon dates in many instances (summarized in Armit, 1996). The archaeology reflects agricultural and pastoral subsistence. Ovicaprid bones and pottery were recovered from the upper levels of the midden at

Livingstone's Cave on Ulva (Bonsall, 1989) and pottery was also recovered from the Oronsay shell middens (Mellars, 1987). Cereal-type pollen was retrieved from pottery shards at Kinloch, Rum (Moffatt, 1990) and charred cereal grains including those of cultivated barley (*Hordeum vulgare*) and rye (*Secale cereale*) were recovered from a pit on Ulva *(Bonsall et al.*, 1991, 1995). Charcoal at the base of the pit was radiocarbon dated to 4990±60 BP (5690 cal. BC) although the cereal grains will presumably be younger than this (Bonsall *et al.*, 1995).

Although it is not possible to identify whether the original Mesolithic inhabitants gradually adopted agricultural practices in the islands or whether they were replaced by immigrants (cf. Armit and Finlayson, 1992) this cultural change is significant both in archaeological terms and in terms of potential differences in environmental exploitation evident.

1.3 The early Holocene pollen record for the Inner Hebrides (cf. Fig. 7.1)

There have been many pollen studies of sites in the west coast of Scotland and near coastal areas (e.g. Nichols, 1967; Rymer, 1977; Birks, 1980; Robinson, 1983; Affleck *et al.*, 1988; Edwards and McIntosh, 1988; Robinson and Dickson, 1988; Haggart and Sutherland, 1992; Rhodes *et al.*, 1992; Tipping, 1992; Walker *et al.*, 1992), particularly in connection with archaeology. Palynological investigations of the Inner Hebridean islands have focused on the larger islands of Skye and Mull and there is little published pollen data for most of the smaller islands (Eigg, Muck, Tiree, Coll, Canna, Ulva). Much of the pollen data from Skye and Mull were used in the reconstruction of Lateglacial environments, and little detailed attention has been paid to Holocene vegetation changes. Emphasis has often been placed on regional vegetation successions rather than local ecologies and potential human impacts, and radiocarbon dates are few, although more recent pollen profiles from Rum and Islay are the exceptions (Hirons and Edwards, 1990; Birks, 1993; Edwards and Berridge, 1994).

1.3.1 Islay and Jura

Little palynological work had taken place on Islay until fieldwalking and excavations linked to the southern Hebrides Mesolithic Project produced discoveries of many areas of Mesolithic and early Neolithic occupation (Mithen and Lake, 1996).

Most of the palynological investigations have taken place on the Rhinns of Islay where the most extensive archaeological sites were discovered and a summary of pollen data from these sites is provided by Edwards (in press). Analyses of two cores from Loch Conailbhe and Coultoon Bog in the southern Rhinns, were hampered by an hiatus in the sediments at Loch Conailbhe and high quantities of deteriorated pollen in the Cultoon material (Bennett, 1989). Nevertheless, the pollen profiles suggest that *Corylus avellana* was dominant in local vegetation in the early Holocene. This compares favourably with pollen data from Loch Gorm (Bunting *et al.*, in press) in the northern Rhinns which also show a high abundance of early postglacial *Corylus avellana*-type pollen, but even greater amounts of ericaceous pollen.

The above pollen profiles are undated but cores from Coulererach (Carp, 1984; Edwards, in press), Gruinart Flats (Edwards, 1998) and Loch a'Bhogiadh (Edwards and Berridge, 1994) on the Rhinns of Islay, and a core from Sorn Valley, Newton (McCullagh, 1991) have been radiocarbon-dated. The pollen from these shows an early postglacial open environment of grasses, herbs and birch which is superceded by the expansion of hazel. The date for the hazel expansion at Gruinart Flats is given as 9170±50 BP (8380 cal. BC) (Edwards, in press) which compares well with data from the southern Hebrides and dates suggested by Birks (1989) and Boyd and Boyd (1990). The published date for the *Corylus* rise at Loch a'Bhogaidh of 10,910±450 BP (10,740 cal. BC) is too old and unlikely to be correct (Edwards and Berridge, 1994; Sugden and Edwards, in press). Although the *Corylus* expansion on Colonsay is relatively early (9850±110 BP [9420 cal. BC]) (Andrews *et al.*, 1987), elsewhere to the north of Islay and Colonsay the *Corylus* expansion is recorded as later (sections 1.3.3, 1.3.4, 1.3.5).

All the pollen data from Islay show that hazel was a major component of vegetation throughout the early Holocene. There are however some temporary reductions recorded in the hazel curves. At Loch a'Bhogaidh a reduction dates to c. 7500 BP (6330 cal. BC) (Edwards and Berridge, 1994) and a similar reduction in the Sorn Valley profile occurs c. 7000 BP (5870 cal. BC) (McCullagh, 1991).

On Islay, *Alnus* pollen increases to its rational limit as other arboreal pollen, including *Corylus avellana*-type, declines (McCullagh, 1991; Edwards and Berridge, 1994; Bunting *et al.*, in press), although there appear to be localised differences between some of the cores. *Calluna vulgaris* is better represented in the Loch Gorm profile (Bunting *et al.*, in press) than elsewhere but decreases as *Alnus* expands. The pollen data from Bealach Froige, albeit undated, show low amounts of *Corylus* and *Alnus* pollen alongside high levels of Poaceae and Cyperaceae (Edwards, in press). While this assemblage may represent later

Holocene environments, at Loch a'Bhogaidh on the Rhinns of Islay, arboreal pollen percentages at this time are low and those of *Calluna vulgaris* high. Carp (1994) also noted that pollen from sediments dated to 4010±75 BP (2500 cal. BC) at Loch Gorm contained high amounts of *Corylus* and *Betula* pollen when by this time these taxa would be expected to be much reduced. Although it is suggested that the pollen derives from re-worked older sediments, it is not inconceivable that pockets of woodland remained undisturbed on Islay until much later in the Holocene.

It may be assumed that vegetation on Jura was similar to that on Islay for the early Holocene period, but there is little pollen evidence available to substantiate this. Pollen from Bird Loch, Jura provides a general picture of Holocene vegetation (Mercer, 1970; Edwards, in press). Pollen counts however were low (150 grains) and the profile was not dated (Mercer, 1970). Pollen in the lower levels is mainly *Betula* and *Corylus*, which reduces as *Alnus* and Ericaceae expand and suggests that the profile pre-dates c. 6500 BP (5460 cal. BC). All arboreal pollen is greatly reduced in the later profile as Poaceae and Cyperaceae increase. Other pollen analyses on Jura were undertaken on a pit fill as part of the archaeological investigations at Lealt Bay, but the pollen is likely to post-date the Mesolithic (Mercer, 1970).

1.3.2 Oronsay and Colonsay

Oronsay itself presents few opportunites for pollen analysis as much of the island is covered in sand. A small mire has been sampled for pollen by Andrews *et al.* (1987), the base of which was radiocarbon dated to 8750±85 BP (7800 cal. BC) where the majority of pollen recorded was *Betula* and *Corylus*. This is likely to represent birch-hazel scrub, pockets of which remain on the islands today (Section 1.1.4). From *c.* 8000 BP to *c.* 3000 BP (6190-1200 cal. BC) there is an hiatus in the peat and no pollen contemporaneous with the middens on Oronsay survives. Andrews *et al.* (1987) also investigated a section of marine silts 50 cm deep from an inter-tidal basin on the Strand at Oronsay. *Corylus, Quercus, Alnus* and *Betula* pollen was present, but the short depth of the profile and the absence of radiocarbon dating make it impossible to correlate with other sites, although Andrews *et al.* (1987) suggest a date of *c.* 6500 BP (5460 cal. BC) in view of the amount of *Alnus* pollen present.

The only published pollen data from Colonsayarefrom Loch Cholla to the south east of the island (Andrews *et al.*, 1987). These display the usual suite of taxa for the early Holocene of *Corylus, Betula*, Poaceae and Cyperaceae. The hazel expansion occurs shortly after 9850±110 BP (9420 cal. BC) and is comparable with evidence from Skye (Birks, 1973; Walker, 1984) for this event. Although not identified as such by Andrews *et al.* (1987), a reduction in the hazel profile shortly after 7870±80 BP (6800 cal. BC) may reflect Mesolithic human activity (Edwards, in press) and further pollen analyses from Loch Cholla and the surrounding peat are currently underway (Boresjza, pers. comm.). The original pollen investigation suffers from the low resolution sampling common in other Inner Hebridean pollen profiles though radiocarbon dates are available.

1.3.3 Mull

Mull is the second largest island of the Inner Hebrides and has been the focus of palynological investigations by Lowe and Walker (1986a, 1986b) and Walker and Lowe (1985, 1987). Pollen analysis of several cores (Fhuaran, Coire Clachach and Torness) from Glen More (central Mull), Mishnish and Beinn Reudle (northern Mull), Gribun (southwest Mull) and Loch an t'Suidhe (Ross of

Mull, southwest Mull) were undertaken by the above authors. Most of the investigations concentrated on the lateglacial environments and the Lateglacial - Holocene transition for which radiocarbon dates were obtained, though low resolution Holocene pollen records for all sites were also published (Lowe and Walker, 1986a; Walker and Lowe, 1985, 1987).

The pollen profiles for the Lateglacial and early Holocene are similar for all sites. *Betula* is the main arboreal pollen type present and with *Juniperus*, Poaceae and Cyperaceae, reflects an environment of open scrub and grassland. *Betula* pollen increases as *Empetrum nigrum* and *Juniperus communis* are reduced. However, there are local variations in the pollen curves. For example, the Beinn Reudle pollen assemblage contains far less *Betula* and *Juniperus* pollen than the other sites (Lowe and Walker, 1986a). Percentages of Lateglacial and early Holocene herbaceous taxa also vary between sites. For example, *Filipendula* pollen is recorded in greater amounts in the early Holocene at Coire Clachach (Walker and Lowe, 1985) than in any of the other profiles.

While all cores show fairly uniform pollen sequences representing the standard Holocene successions of *Corylus, Quercus, Ulmus* and *Alnus*, local variations in the pollen taxa are again evident. *Calluna vulgaris* and other ericaceous pollen is better represented at Mishnish and Beinn Reudle (Lowe and Walker, 1986a), and whilst at most sites *Calluna* pollen expands following the major expansion of *Alnus*, at Beinn Reudle the *Calluna* expansion preceeds that of *Alnus* (Lowe and Walker, 1986a). Only one radiocarbon date is available for the above changes, and this dates the *Corylus* expansion at Torness to 8760±140 BP (7900 cal. BC) (Walker and Lowe, 1985). This is late compared with most of the evidence for Islay and is possibly a local phenomenon due to localised environmental conditions. However, anomalously late dates for the *Corylus* expansion also occur on Skye (Birks, 1973; Vasari, 1977; Walker, 1984).

All sites on Mull show a reduction in arboreal pollen and expansions in *Calluna vulgaris* and a variety of herbaceous taxa in the later Holocene sediments. The degree of expansion of ericaceous and herbaceous pollen differs between sites but there is an overall indication of a reduction in tree cover and an expansion of moor and grassland (Walker and Lowe, 1985; Lowe and Walker, 1986a, 1986b; Walker and Lowe, 1987).

1.3.4 Rum

There are few pollen data from the island of Rum. A core from Long Loch, Rum provides a record of early Holocene environments characterised by an expansions of *Betula, Juniperus* and subsequently *Corylus* pollen (Ford, 1976 cited in Parish, 1990), but no other pollen evidence from the island is as early as this. The rest of the palynological investigations on Rum have been connected to the excavation of the site at Farm Fields, Kinloch (Hirons and Edwards, 1990). This site has a basal radiocarbon date of 7800+75 BP (6640 cal. BC) at which time arboreal pollen is poorly represented and the assemblage is dominated by Poaceae, Cyperaceae and *Filipendula. Corylus* and *Salix* are present in low amounts and an expansion of *Corylus* which probably post-dates the rational hazel rise occurs slightly later. *Betula* and *Pinus* pollen are also recorded.

The expansion of *Alnus* pollen in the Farm Fields monolith is dated to 6430±90 BP (5400 cal. BC) and alder is hardly recorded prior to this despite the amount of pollen present in the earlier dated contexts from the excavation area to the east (see below). Subsequent fluctuations in the *Alnus* curve and other data, especially marked charcoal peaks, are interpreted by Hirons and Edwards (1990) as being possible reflections of human impacts. *Alnus* pollen occurs in a pollen profile from the Kinloch Glen to the west of Farm Fields (Parish, 1990) but its percentage values are very low and erratic (as are those of other arboreal taxa) and do not display the perturbations seen in the Farm Fields profile.

After *c.* 3950 BP (2540 cal. BC), both *Alnus* and *Corylus* pollen decline (Hirons and Edwards, 1990). A similar decline is seen in the Kinloch Glen pollen profiles (Parish, 1990). At Farm Fields, the decline in woodland is accompanied by an expansion in Poaceae and herbaceous pollen, notably *Potentilla*-type, and the first cereal-type pollen occurs.

Pollen and macrofossil analysis of contexts from the Farm Fields excavation were also undertaken and although most contained little or no identifiable pollen, other samples complementthe environmental reconstruction of the Farm Fields area (Moffatt, 1990). Two of the contexts analysed were radiocarbon-dated. The earlier context dates to 7925±65 BP (6830 cal. BC) and this precedes the basal date of the Hirons and Edwards (1990) monolith. Poaceae and ericaceous pollen have the highest representation in the sample, although some *Betula* and *Quercus* pollen is present. The second sample had a later date of 7850±50 BP

BC) (Moffatt, 1990). This again shows similarities to the pollen from other contexts at the site, the main components of the assemblage being *Alnus*, Poaceae, Cyperaceae, Ericales and a range of ruderal pollen types. It is likely that all the pollen from the excavation site derived from very local sources.

Cereal pollen was also detected on pottery from Neolithic contexts from the excavation (Moffatt, 1990). This suggests that human agency may have been responsible for the final reduction in woodland species at the site.

The pollen data from the Farm Fields area, Kinloch, Rum provides a very different picture of past vegetation cover compared to pollen records from other Inner Hebridean islands. *Corylus avellana*-type pollen is recorded in much lower amounts, as is arboreal pollen in general, and ericaceous and herbaceous pollen are recorded in greater quantities earlier than elsewhere. The relative paucity of woodland representation in the pollen at the site may be a reflection of the unsuitability of the environment of Rum for the growth of trees, or may be linked to early and continued human occupation.

1.3.5 Skye

Skye is the largest and most northerly of the island chain and pollen investigations here have been undertaken by Vasari and Vasari (1968), Birks (1970, 1973, 1993), Vasari (1977), Williams (1977), Birks and Williams (1983) and Walker and Lowe (1990, 1991a, 1991b). Many of the studies focus on the Lateglacial to Holocene transition and indicate that Poaceae, Cyperaceae, *Rumex*, *Thalictrum*, *Empetrum* and *Betula nana* were the major taxa present in the Lateglacial. In the succession to early Holocene, *Juniperus communis* and *Betula* are succeeded by *Corylus avellana* and *Salix*. Despite the similarities between profiles, there are local differences in the pollen assemblages. Walker and Lowe (1990) note that *Pinus* pollen is better represented in a core from Elgol than elsewhere, and here *Juniperus communis* and *Salix* pollen percentages are low.

Of the main Holocene vegetation successions, the focal point of interest has been that of the expansion of *Corylus avellana*-type pollen where this has reached its rational limits. Radiocarbon dates for this event are available on a number of cores and in general this occurs around 9500 BP (8900 cal. BC) (Birks, 1973; Vasari, 1977; Walker and Lowe, 1990). However, it is noted by Vasari (1977) that several dates for the hazel rise on Skye are anomalous. The hazel rise at Loch Fada dates to 7500±120 BP (6340 cal. BC) (Birks, 1973) and at Loch Choira Ghobhain to 8650±150 BP (7840 cal. BC). It was suggested by Vasari (1977) that these dates could be wrong but subsequent dates on cores from Coire Laggan and Glen Varragil of 7780±180 BP (6660 cal. BC) and 8175±85 BP (7250 cal. BC) respectively (Walker, 1984), suggest that there is local variation in the expansion of hazel on Skye as withLateglacial taxa mentioned above, and this may be linked to local environmental conditions. Human activity inferred from the pollen diagrams from Skye relates to the last half of the Holocene only (Vasari and Vasari, 1968; Birks and Williams, 1983; Birks, 1993).

1.4 Reasons for further pollen analysis in the Inner Hebrides

The above demonstrates that some of the Inner Hebridean islands are rich in archaeological evidence for early Holocene human occupation and it is unlikely that all islands have both Mesolithic and Neolithic finds, even if they remain to be discovered. There is also an abundance of sites suitable for palaeoenvironmental, particularly archaeopalynological, investigations and there is consequently a high probability that early prehistoric human impacts will be detectable in the pollen records from the area. This means that there is the potential for the discovery of a former human presence where there is currently little or no archaeological evidence available. Indeed, there have been frequent inferences from pollen data of the Outer Hebrides, Shetland and Orkney of early, especially Mesolithic, occupation (Bennett *et al.*, 1990; 1992; Bunting, 1994; Edwards, 1996; Fossitt, 1996). From these islands only Orkney provides evidence of Mesolithic occupation in the form of stone tools which are largely unprovenanced (Saville, 1996). The validity of an anthropogenic interpretation in such instances may be tested more confidently by comparison with pollen data from sites in proximity to areas of known human occupation.

Pollen analysis of sites within the Inner Hebrides is not only important in terms of archaeological application. The delimitation of vegetational successions is also important to the understanding of past and changing environments in the islands and in northern Europe as a whole (Huntley and Birks, 1983). It was mentioned in Section 1.3 that many pollen diagrams from the Inner Hebrides are poorly dated, and estimates for vegetational transitions have been made by comparison with diagrams from elsewhere in Scotland and the British Isles. This may mean that pollen isochrones for the Inner Hebrides are inaccurate. Indeed, isochrones suggested by Birks (1989) rely on data from only 8 sites, and 5 of these are from Skye. Modifications to previously suggested isochrones for *Corylus* and *Ulmus* based on information from a greater number of more recent and radiocarbon-dated pollen diagrams were made by Whittington and Edwards (1997) but there still remains a need for more detail to produce a more accurate picture of palaeovegetational successions.

The arrival and expansion of *Corylus avellana* in the British Isles in the early Holocene has long been the subject of debate. Original estimates for the colonization of the Inner Hebridean islands by this taxon suggest that it was established by 9500 BP (8900 cal. BC) (Birks, 1989). Whilst it has usually been assumed that climate was the controlling factor in the spread of this taxon, Huntley (1993) suggests that other factors including soil stability and human assistance should be considered. The topographic variability of the Inner Hebridean islands has been mentioned in Section 1.2. Geomorphology and topography will obviously have influenced soils in the past, hence there may be considerable differences between islands (and indeed within islands) for the timing of their colonization by hazel and other species, as suggested above. There is clearly a need not only for more pollen diagrams from the Inner Hebrides, but for more radiocarbon-dating of profiles.

Peaks in microscopic charcoal have frequently been interpreted as the product of human domestic activity (Edwards, 1990a) or the burning of vegetation (Smith, 1970; Simmons *et al.*, 1981). However, there may be non-anthropogenic explanations for high levels of microscopic charcoal (e.g. reworking of sediment; increase in airborne particulates due to change in climate and weather patterns [Edwards, 1990a; Tipping, 1996], and lightning strikes [Patterson *et al.*, 1987; Edwards, 1990a]), which may also have implications for the interpretation of pollen diagrams. Most of the pollen data from the Inner Hebrides lack associated microscopic charcoal quantification, yet this would appear to be a necessary component of palaeoenvironmental investigation in order to contribute to the evidence for the influences of climatic, ecological and human events.

Palynological investigation has been undertaken on many of the Inner Hebridean islands, but there are limitations to the interpretation of these data. The problems of low sampling resolution, lack of quantification of microscopic charcoal and insufficient radiocarbon dates have already been mentioned, as well as a concentration on Lateglacial rather than Holocene environments. Hence additional pollen profiles combined with microscopic charcoal data, close resolution sampling and radiocarbon dates would enhance the palaeoenvironmental record for the islands. In addition, the multiple coring of single sites has a greater potential than a single core to produce an accurate reconstruction of local vegetation through time (Edwards, 1983). Intra-site variations in pollen profiles may aid interpretation of what is regional and local, or of natural or human origins. Multiple profiles will also increase the probability of detecting small scale local impacts and may suggest a spatial biassing of these events. An elaboration of this is given in Section 2.1.

CHAPTER 2 - METHODS AND SITE SELECTION

2.1 Methods

In discussing the requirements of further pollen work in the Inner Hebrides in the previous chapter, it was mentioned that certain methods should be employed, the main methods being;

1. Multiple coring of single sites.
2. Close resolution pollen sampling.
3. Microscopic charcoal quantification.
4. AMS radiocarbon dating of sediment profiles to provide a chronology and to allow reliable intra- and inter-site comparisons.

These are used here and other methods employed are:

5. Loss on ignition analysis.
6. Low power (x100) scanning of complete 1cm^3 samples to maximise cereal pollen detection.
7. Classification and quantification of damaged pollen.
8. Dinoflagellate analysis of some sediments.

2.1.1 Multiple coring

Although comparisons between pollen profiles have long been made over large areas including the Inner Hebrides and islands such as Mull and Skye (cf. Birks, 1973; Vasari, 1977; Walker and Lowe, 1985, 1987, 1990, 1991a, 1991b; Lowe and Walker, 1986), multiple profile studies of single basins are rare. Three pollen profiles are available from Loch a'Bhogaidh, Islay (Agnew *et al.*, 1988;

Edwards and Berridge, 1994) and two from Machrie Moor on Arran (Edwards and McIntosh, 1988; Robinson and Dickson, 1988). Multiple profile studies may be considered necessary for projects where small scale localised changes in pollen profiles need to be detected as, in general, studies relying on a single core will not provide a good representation of very local vegetation communities and their dynamics through time. Centrally placed cores may reflect wider regional vegetation changes due to the taphonomic factors influencing pollen dispersal and a different range of taxa may be recorded from different parts of a site due to local ecological differences (cf. Turner, 1975; Edwards, 1982, 1983). In addition, early Holocene human impacts are likely to have been short-lived and spatially constrained, hence their impact on the pollen record may not be wide-ranging. When the taphonomic variables affecting pollen input to a lake or bog are also taken into account, then a single core may not be representative of either regional or local vegetation.

Multiple cores from a peat basin will normally incorporate temporal and spatial differences in the pollen profiles (Turner, 1975; Edwards, 1983; Turner *et al.*, 1993) but it is often assumed that sediment focusing in lakes results in an overall smoothing of the fossil pollen record, and that lake-derived pollen profiles have uniform characteristics (Jackson, 1994). Evidence for the behaviour of pollen in lakes and peat bogs is given below, in addition to evidence supporting multiple profiling methods.

2.1.1.1 Pollen distribution and multiple coring in lake sediments

Studies on the dispersal and influx of fresh pollen into lake basins have shown that wind direction, wave action, pollen grain morphology and density, lake morphometry, seasonality and thermal stratification may influence initial pollen deposition at the water-sediment interface (Pennington, 1947, 1973, 1979; Davis *et al.*, 1969; Brush and Brush, 1972; Davis, 1973; Davis and Brubaker, 1973; Bonny, 1978) but sediment focusing is usually assumed to negate substantial differences resulting from the effects of these variables (Davis *et al.*, 1969; Davis and Brubaker, 1973; Jackson, 1994). Nevertheless, Davis *et al.*, (1969), Edwards (1983) and Bonny *et al.*, (1984) have queried the reliability of a single core as an adequate sample of a pollen record in a lake. While Davis (1973) showed that pollen is not mixed independently of sediment once deposited and therefore may not be subject to the same variables as fresh pollen, it appears that the extent of sediment focusing is dependent upon the morphometry of the lake basin and this may occur to different degrees in different lakes. Indeed, morphometry may influence whether or not sediment mixing and focusing occurs at all (Davis, 1973; Chen, 1987). Sediment focusing is greater when seasonal thermal stratification of lake waters occurs which creates waves at depth and annual water turnover. In non-thermally stratified lakes, there is little or no turnover and sediment focusing is reduced or conceivably absent. Large lakes made up of smaller independent basins are unlikely to become thermally stratified (e.g. Lake Windermere, [Pennington, 1947]).

Where sediment focusing is low or absent, then the factors which affect the initial distribution of pollen over lake surface sediments are of greater significance. The pollen content of samples of sediment units from within a lake were statistically tested for uniformity by Davis *et al.* (1969) and significant variations in pollen content were detected in strata only a few metres apart. Davis and Brubaker (1973) have shown that small pollen grains of low density are more susceptible to wind-driven currents than heavier pollen. Davis and Brubaker (1973) also showed that aerially derived pollen is likely to be greater in surface sediments at the centre of a lake as it is delivered directly to the water body and may sink quickly, whereas locally derived pollen and stream-borne inputs will be greater in the sediment at a lake edge. Pennington (1947) recorded greater amounts of *Pinus* pollen in the northern basin of lake Windermere than in sediments at its perimeter. As *Pinus* grains are particularly buoyant in air, this suggests that the lake centre was receiving greater amounts of airborne pollen. *Pinus* may not have been redistributed quickly by wave action if water movement was low and rapid sinkage may have occurred due to the the air sacs of the pollen grains filling rapidly with water. Chen (1987) also noted that pollen distribution in a non-stratified lake will be affected by the pollen source.

Pennington (1973, 1979) found that larger lakes with no inflow streams receive a greater amount of regional pollen whereas lakes with inflow streams may receive more local pollen although if inflow streams are many and drain a large catchment then pollen from a large area would be transported into lake waters and contained within the fossil pollen record of its sediments. Variations in pollen influx rate around a lake edge may over-represent stream-side plants in the pollen record (Bonny, 1978) and although proportions of fossil pollen between cores may be similar due to sediment focusing, concentrations and influx rates may differ (Bonny *et al.*, 1984). It may be argued that a knowledge of the different pollen concentrations, pollen influx rates and sediment accumulation rates within a lake basin is necessary for an understanding of the dynamics of a system through time, including interpretation of the pollen curves and definition of a related catchment area (Bonny *et al.*, 1984). Indeed, Pennington (1972) suggests that climatic and environmental changes through time may alter the throughput of water in a lake basin and thus sediment focusing and pollen influx.

Consideration must also be given to the pollen catchment areas represented by the airborne and stream-borne pollen components. As airborne pollen is more likely to derive from a wider area, then local variations in lake-side vegetation will be diluted in the pollen rain from a wider area in centralised cores. Stream-borne pollen representing a smaller catchment area is more likely to reflect lake-side changes, although multiple lake edge cores will perhaps be needed to detect these (Bonny, 1978), particularly if the instigator of ecological change, such as human occupation or the grazing of animals, moves through time (cf. Edwards, 1982).

Much of the above evidence is derived from studies on fresh pollen within lake basins, and there are few studies on the variations of fossil pollen spectra within a lake. Edwards (1982, 1983) and Edwards and Thompson (1984) suggested that single cores from lakes may miss detail and this is borne out by the results of Whittington *et al.*, (1991a) from Black Loch, Fife. An event registered in zone BLIVd on a core from the loch edge is not apparent in any other cores from the site and the suggestion is made that this zone has registered the effects of localized Mesolithic impacts. A similar effect was recorded by Bos and Janssen (1996) when pollen investigations of two cores, one from deep water sediments in a lake and the other from lake edge sediments, were undertaken. Despite providing the greatest depth of resolution, the deep water core lacked the detail recorded at the lake edge. The shorter core contained reductions in *Pinus* pollen (locally present) which appeared to be cyclical and coincided with Palaeolithic occupations indicated by the local presence of Palaeolithic artefacts.

There can be little certainty about which variables may have affected pollen and sediment distribution in the past (Edwards and Whittington, 1993) as lake morphometry, the thermal regime of lake waters and wind directions can change through time, and hiatuses in sedimentation within lake basins can also occur, thus interrupting the pollen record (e.g. Bennett, 1989; Whittington *et al.*, 1991; Edwards and Berridge, 1994). Such factors mean that the general rules usually followed for core location may be inadequate (Jacobson and Bradshaw, 1981), particularly when the detection of small scale impacts in the pollen record is the investigator's aim.

2.1.1.2 Multiple coring of peat

It has long been recognised that fossil pollen from peat cores may vary spatially depending on the core position within the peat body (Turner, 1975). This is the result of pollen dispersal mechanisms. Large bogs with open centres may receive greater amounts of airborne pollen which is likely to derive from trees and shrubs in the wider catchment area, whereas bog edges may trap more local pollen if screening by local woodland occurs (Tauber, 1965, 1967; Turner, 1975; Janssen, 1977; Jacobson and Bradshaw, 1981; Edwards, 1982, 1983). Therefore, in peat which was previously well wooded, it is probable that most fossil pollen will have originated close to the coring site (Tauber, 1965, 1967; Edwards, 1991).

Caseldine (1981) has shown from surface pollen studies that woodland surrounding a bog acts as an effective filter to most types of pollen derived from pastureland further afield. His work also supports the (distance decay) theory that higher ratios of woodland pollen occur at a bog edge and reduces in proportion to local pollen towards the centre of the bog. Tinsley and Smith

(1974) showed a similar effect on *Quercus* pollen which decreases with distance from the woodland edge.

Caseldine (1981) also demonstrated that larger Poaceae pollen grains are concentrated at the bog edge and that grain diameters decrease with distance to the centre of the bog. This means that although some pollen types may permeate the woodland boundary, there is preferential distribution of the grains by size. Edwards (1982) suggested that this is another component is the problematic detection of cereal pollen, which is larger and heavier than most other types of Poaceae and is not widely dispersed.

Multiple profile studies of fossil pollen in peat do not always show differences. For example, profiles from Bloak Moss and Kennox Moss, Ayrshire were intended to demonstrate the variability in pollen content of cores from a single bog but, the pollen record from all three cores was remarkably similar (Turner, 1975). The cores were positioned approximately 500 m apart and in central positions and are therefore more likely to have received a large regional pollen component compared to cores situated at the bog edge (Edwards, 1982 and cf. Janssen, 1977; Caseldine, 1981). Other multiple profile studies in peat may provide records of 'local differences', but the cores are often from separate basins and kilometres apart (e.g. Rannoch Moor, [Walker and Lowe, 1981]; coastal plain of north Ayrshire [Boyd, 1988]).

As smaller bogs may receive a lower component of aerial pollen they may also provide records of very local vegetation changes. Studies at Cross Mere, Ayrshire were undertaken Turner (1984) where five cores no more than 500 m apart were analysed. Whilst certain similarities were displayed in the pollen records, statistically significant differences were also noted in some of the profiles. These were interpreted by Turner as the reflections of different local environmental conditions. Smith and Cloutman (1988) also noted broad scale similarities but many local differences in a study of sixteen cores from a small bog of 250 m in area, Waun-Fignen-Felen in South Wales. Simmons and Innes (1988) also advocated fine resolution multiple profile analysis of peat bogs, particularly where the aim is to detect small scale, local changes in vegetation.

There are therefore many reasons for the differential dispersal of pollen over a bog. Screening out of certain pollen types by local vegetation, pollen size and local ecological differences will all influence pollen distribution as may basin size and the relation of pollen source to the basin. Multiple coring of a single peat-filled basin will therefore provide the most complete record of changes of local vegetation through time, provided cores are not confined to the centre of the basin, and include sites at the bog edge. This will increase the probability of the detection of early prehistoric human impacts, as these are likely to have produced localised effects.

2.1.2 Microscopic charcoal: problems for distribution and taphonomy

The occurrence of microscopic charcoal in pollen preparations is usually interpreted as an indication of fire in the history of a pollen catchment (which may, or may not, correspond with the charcoal catchment area [cf. Edwards and Whittington, in press]). Fires may be caused by various natural means including lightning strikes (Patterson *et al.*, 1987) and by accidental or intentional burning by humans (cf. Edwards, 1990). Differences in the types of material combusted (e.g. hardwood, softwood, grass) and in fire intensity may produce charcoal in varying sizes and amounts (Patterson *et al*; 1987; Moore, 1996).

Microscopic charcoal may be representative of local fires, but there are arguments that it may derive from further afield. Patterson *et al.*, (1987) summarized the variables influencing charcoal production and distribution and suggest that in general terms, small particles of charcoal are spread over a wider area than large particles. Clark (1988) also showed that smaller particles of the size usually seen in pollen preparations (5-20 μm) are far more likely to become airborne. This has led to arguments that microscopic charcoal in pollen preparations derives from a wide area and that peaks may be a reflection of increases in fire distribution and periodicity due to natural factors such as climatic change (Tipping, 1996).

It has also been suggested that human agency (accidental or intentional) may have been responsible for fire throughout prehistory in order to promote fresh growth of vegetation or to drive game (Smith, 1970; Jacobi *et al.*, 1976; Simmons *et al.*, 1981). Edwards (1990) received evidence where some increases of *Alnus glutinosa* pollen were coincidental with increases in microscopic charcoal, but in many cases the *Alnus* pollen and microscopic charcoal profiles did not appear to be interdependent. Similarly, Edwards (*ibid*) found that increases in *Corylus avellana*-type pollen were not accompanied by increases in microscopic charcoal although an anthropogenic interpretation has often been ascribed to this phenomenon (Smith, 1970, 1984). Even when microscopic charcoal is recorded in pollen deposits, there can be no direct evidence to confirm that this was produced by local human activity. Tipping (1996) acknowledges that where archaeological evidence is present, particularly when close resolution and spatial sampling methods are employed in palaeoecological analysis, then links between fire episodes and human activity may be drawn.

This does not necessarily mean that charcoal abundance is a direct result of the direct burning of vegetation. An abundance of domestic fires may also increase microscopic charcoal, both in the atmosphere and in soils, and this may reach pollen sites if local, or from further afield when woodland surrounding a site, which may have acted as a screen to microscopic charcoal, has been removed (Edwards, 1990).

Whilst airborne charcoal may be locally produced or may be derived from sources further afield, microscopic charcoal may reach a lake or peat bog by other means, such as inwash by streams, erosion due to increased runoff caused by a reduction in surface vegetation (Patterson *et al.*, 1987) and landslips (Whitlock and Milspaugh, 1996). In some instances the fire may occur on a peat bog itself (Jacobi *et al.*, 1987; Caseldine and Hatton, 1993; Turner *et al.*, 1993), or at a lake edge, when burnt vegetation may fall directly onto sediments (Whitlock and Milspaugh, 1996). Clark (1988) proposed that the small sizes of charcoal usually seen in pollen slides are unlikely to derive from stream- and surface-borne sources, and that the larger particles transported by these methods are better detected by thin section analyses of sediments. He also cited evidence which shows that little charcoal is removed from its source by erosion and runoff. An opposing view is provided by Patterson *et al.*, (1987) and studies of sediments from various lake catchments in the Yellowstone National Park by Whitlock and Milspaugh (1996) showed that erosion and runoff are major mechanisms for the introduction of charcoal, but particularly macroscopic charcoal, into lake sediments. Evidence from Patterson (1978) indicated that charcoal in lake sediments is higher near inlet streams and quantities of microscopic charcoal are also known to be higher in minerogenic runoff.

Increases in charcoal in laminated lake sediments have been correlated with fire events recorded as fire scars on trees in North America (Swain, 1973; Clark, 1988) and northeastern Europe (Tolonen, 1983; Lehtonen and Huttunen, 1997). Whilst fires in a lake catchment are normally represented by increases in macroscopic charcoal (e.g. Clark, 1988; Lehtonen and Huttunen, 1997), increases in microscopic charcoal (such as that counted in pollen preparations) do not always occur (Swain, 1973; Clark, 1988). Swain (1977) suggests that the sampling resolutions used in pollen analysis may prevent peaks in microscopic charcoal being detected, but taphonomy may also be a cause. Clark (1988) remarks that microscopic charcoal is far more likely to derive from the fallout of airborne particles from a wide area whereas macroscopic charcoal will travel less far and is more likely to erode into a lake. Nevertheless, increases in microscopic charcoal which correlate with known fire events may still be detected in pollen preparations (Cwynar, 1977).

It cannot be assumed that microscopic charcoal is subject to the same distribution processes as pollen, as it has a different taphonomy and behaves differently in air and water (Clark, 1988; Edwards and Whittington, in press). The taphonomy of microscopic charcoal may also promote its differential distribution in lake sediments and peat bogs, and charcoal records from both environments are discussed below.

2.1.2.1 Microscopic charcoal in lake sediments

Once charcoal is incorporated into lake sediments, then any sediment focusing which occurs should act on the charcoal content of the sediment in a similar manner to the pollen (refer to section 2.1.1.1). The potential for the differential distribution of pollen in lake sediments suggests that microscopic charcoal may not be evenly distributed within a lake and may appear in variable quantities in different profiles from the basin (Bradbury, 1996).

The most recent and comprehensive study of fire events and charcoal distribution in lake sediments is that of Whitlock and Milspaugh (1996). Whilst it included an analysis of spatial distribution it also involved analysis on a short-term temporal scale. The study quantified macroscopic charcoal in a number of lakes in the Yellowstone National Park, North America, associated with local fires in 1988, and incorporates lakes of different depths with both burned and unburned catchments where sampling for charcoal was undertaken along transects following wind directions at the time of burning. In addition to the information regarding the methods by which charcoal may enter lake sediments, their study is invaluable in identifying some of the factors which may influence charcoal distribution within the lake itself. Whilst the study relates to macroscopic charcoal, different size ranges were quantified and for all the size ranges charcoal distribution patterns appeared to be the same, although a greater amount of small sized fragments were present in all samples. Despite the problems regarding the taphonomy of microscopic charcoal mentioned above (Section 2.1.2) it is possible that microscopic charcoal originating from fire events within a lake catchment may register a similar signal to macroscopic charcoal entering the lake.

Conclusions drawn by Whitlock and Millspaugh (1996) are summarized as follows:-

1. Charcoal was incorporated into sediments of lakes with unburned catchments suggesting an airborne fallout.

2. Deep lakes show higher charcoal concentrations in the shallow littoral zone (even when the catchment is unburned and charcoal input is aerially derived).

3. Deep lakes with unburned catchments show no increase in charcoal in deep water sediments through time in accordance with fire events.

4. Shallow lakes show no clear spatial patterns in charcoal distribution, but show increases through time linked to fire events.

5. Peaks in charcoal (i.e. increases above the background noise) are representative of actual fire events.

The variations in charcoal distributions in lakes within Yellowstone National Park suggest that multiple coring of lake sediments is imperative forachieving a representative record of local fire events, particularly when lakes are infilled and the previous morphology of the basin in not completely known. Indeed, the results of Whitlock and Milspaugh (1996) indicate that the best charcoal record, particularly for local fire events, may be detected in lake edge sediments. Edwards and Whittington (in press) also suggest that it may be possible to infer the distance of a fire or series of fire events from the coring site using multiple lake profile pollen and charcoal data, although inferences from current palaeoevironmental data are inconclusive. As single cores from lake sites are usually centrally placed (and may therefore receive a greater amount of airborne particulates [Section 2.1.1.1]), the variations in charcoal data in the above studies indicate a need for multiple profiles in order to elucidate interpretation of the fossil charcoal record.

2.1.2.2 Microscopic charcoal in peat bogs

Unfortunately, most of the studies on the taphonomy and distribution of microscopic charcoal have been made on lake sediments. There is little information about the behaviour of charcoal in peat (Patterson *et al.*, 1987). It may be assumed that peat bogs receive a general background of aerial fallout and that local fire events will register by increasing the input of aerially dispersed charcoal to bogs. In topographic mires charcoal input may also be increased by runoff and stream deposition. Spatially and temporally diverse charcoal representations in multiple profiles from North Gill, Yorkshire, suggest that very local fires increase microscopic charcoal at the site of burning (Turner *et al.*, 1993). In some cases, where intense burning occurs directly on a peat bog, then the burnt layers should be visible in the peat stratigraphy, and hiatuses should be apparent in the palaeoecological record (Moore, 1975).

2.1.3 Interpretation of microscopic charcoal in pollen preparations

A certain degree of caution over anthropogenic interpretation of charcoal events must be maintained when archaeological evidence is not present and consideration must be given to changes in the fallout of long distance charcoal and the reworking of old charcoal (Edwards, 1990a; Tipping, 1996). It is noted by Whitlock and Milspaugh (1996) that there is currently no reliable method for the determination of distance of a fire event from the charcoal-receiving site and little is known about European fire histories and connections to climate. Most data relating to the fire in ecological systems derives from North American, Australian and Scandinavian examples, where climate and ecology differ from those for northwest Britain. However, the above sections suggest that the quantification of microscopic charcoal in pollen preparations may aid the interpretation of pollen profiles. When reinforced with archaeological data and considered as part of an environmental assemblage, then charcoal records may assist in the understanding of vegetation changes.

2.1.4 Quantification of microscopic charcoal

Microscopic charcoal was assessed on all levels sampled and counted for pollen from the cores in this study. It was initially intended to use the point count estimation method (Clark, 1982) but concentrations were not sufficient to provide a statistically reliable sample size in the first few levels tested and this method was abandoned. Charcoal particles were quantified by two dimensional measurement (length and breadth) and concentrations expressed as total surface area per sample volume ($cm^2\ cm^{-3}$). Charcoal to pollen ratios (Ch:P) were also calculated in order to identify false charcoal peaks arising from variations in sediment accumulation rates (Swain, 1973). Charcoal influx is defined as charcoal accumulation rates in units of $cm^2\ cm^{-3}\ yr^{-1}$.

Edwards and Whittington (in press) presented microscopic charcoal data from multiple lake profiles using the three methods described above. For single profiles the curves for charcoal concentration, Ch:P and charcoal influx appeared very similar and where one curve increased the others increased. Although microscopical charcoal has been quantified using all three methods in this study, Ch:P is usually referred to for ease of interpretation. Comments regarding charcoal concentrations and influx refer to unique events in their profiles which may enhance interpretation.

2.1.5 AMS radiocarbon dating of pollen profiles

The necessity to compare pollen profiles from this study with each other and existing profiles within the Inner Hebridean islands and elsewhere, and the potential for matching pollen profile changes with periods of prehistoric occupation near the pollen sites, demands that the cores should be dated. Radiocarbon dates are also necessary to confirm the contemporaneity of palynological features recorded in multiple cores from a single site. Close resolution sampling, including 1 cm contiguous samples in places, means that AMS dates are preferable as they are capable of providing a higher resolution than is normally the case with radiometric determinations.

2.1.5.1 Choice of levels for dating

The choice of levels for dating was based on features in the pollen diagrams where reductions and recoveries of certain taxa occurred, and where initial expansions in taxa appeared (e.g. *Corylus* rise, *Alnus* rise). Dating of the latter would contribute to refinement of pollen isochrone maps and the timing of the expansion of these taxa within the early Holocene .

2.1.5.2 Processing of samples

Processing of 49 ^{14}C samples to graphite targets was carried out by the NERC Radiocarbon Laboratory at East Kilbride, Scotland, under the supervision of Dr. Charlotte Bryant. This was followed by AMS dating of 48 samples at the University of Arizona USF-AMS facility and of 1 sample by the Lawrence Livermore Radiocarbon Laboratory. Tables of results including laboratory codes are provided for each site (Vol. 2).

2.1.5.3 Calibration of dates

The calibration of AMS dates was achieved using Calib3 (Stuiver and Reimer, 1993; Appendix A). Calibrated dates, generally on spot dates, are provided in brackets within the text, and the main interpretations rely upon uncalibrated dates in radiocarbon years BP. This is to facilitate comparisons with the wider palaeoecological literature, and dates for much of the archaeological evidence in the Inner Hebridean islands are also presented in this form. The calibration of dates results in a range of error over which the actual date may occur which makes comparisons extremely difficult.

2.1.5.4 Extrapolation of dates and the construction of age/depth curves

The extrapolation of dates to allow the calculation of pollen influx and sediment accumulation rates for each profile was achieved using TILIA (Grimm, 1991). Linear extrapolation appeared to be most appropriate as pollen influx for published Inner Hebridean pollen profiles has been calculated using this method (e.g. Edwards and Berridge, 1994) which makes fewer assumptions of the data compared to other methods such as cubic spline interpolation or construction of a polynomial curve (Bennett, 1994). As linear interpolation does not take into account standard deviation errors or reversals of dates (unlike a polynomial curve) some dates which appeared erroneous have been excluded from calculations and are discussed in the following chapters where appropriate.

Pollen influx is defined as the amount of pollen present in 1cm^3 of sediment for each radiocarbon year (= pollen accumulation rate of grains cm^{-3} yr^{-1}).

Age/depth curves based on uncalibrated radiocarbon dates were constructed for each profile where an appropriate number of dates was available.

2.1.6 The detection of cereal-type pollen grains

2.1.6.1 Cereal scanning

Cereal-type pollen grains in the original core from Kinloch, Rum (Hirons and Edwards, 1990) indicated agriculture as early as c. 3950 BP (2540 cal. BC). As cereal pollen is produced in very low amounts (O'Connell, 1987; Edwards and McIntosh, 1988) and does not travel far from its source (Vuorela, 1973; O'Connell, 1986; Hall, 1989), it was decided to maximise the detection rate of early cereal-type pollen on cores from Rum, and subsequently on cores from Ulva (in which cereal-type pollen also occurred during routine counting) by employing a low power scanning method.

Originally developed and discussed by Edwards and McIntosh (1988), the method involves the low power (x 100) microscope scanning of pollen preparations. As cereal-type pollen grains are large (> 37µm) they are more easily identified at low power than most other pollen grains. This method allows a greater proportion of each sampled level to be searched for cereal-type pollen, where thousands of grains may be present and where the amount of time involved in pollen counting or scanning at a higher power (e.g. x 400) would be prohibitive.

Estimations of total pollen content of scanned samples were obtained by counting land pollen over transects on each slide viewed at x 400. The area covered in counting could then be compared to the whole area scanned and an estimation of total pollen scanned was calculated. Total amounts of land pollen present in 1 cm^3 samples are dictated by pollen concentrations, and pollen densities on slides may also vary due to dilution with silicone oil. It was usually possible to scan between an estimated 5000 and 10,000 land pollen, but in some samples, extremely low concentrations meant that as few as 1000 land pollen were scanned. The estimated amounts of pollen scanned in each sample are provided in Appendix B.

1 cm thick, contiguous samples were scanned for cereal-type pollen on parts of monoliths KLI, KL3 and KL4 from Rum and additional samples from below the earliest level where cereal-type pollen was previously detected on K (Edwards and Hirons, 1990) were also processed. 1 cm sampling resolution was also employed on parts of cores AC1, AC2, LC1 and LC2 from Ulva. Where additional cereal-type pollen was detected the sample was also counted for land pollen to the standard 500 land pollen sum (see below, Section 2.1.7). This enabled the range of pollen types to be assessed for other indications of agricultural activity.

2.1.6.2 Criteria for identification of cereal-type pollen

The identification of cereal-type pollen was based initially on the size classification given in Moore *et al.*, (1991). Poaceae grains exceeding 37 μm in diameter with an annulus > 8 μm were thus considered for classification as cereal-type pollen, although the surface pattern (scabrate) and the strength of the annulus boundary were also taken into consideration (Andersen, 1979). Grains exceeding 40 μm in diameter with an annulus > 10 μm and a verrucate surface pattern were considered for inclusion in the *Avena-Triticum* type category (Andersen, 1979; Moore *et al.*, 1991).

Unfortunately there were too few grains recorded to test statistically for the reliablity of identification, and large Poaceae pollen types such as the *Glyceria* group may fall into the cereal-type category using the above criteria (Andersen, 1979; O'Connell, 1987). Hence the accompanying pollen spectra, radiocarbon dates and proximity of archaeological evidence to the site are all the more important to interpretation.

2.1.7 Damaged pollen

The physical and chemical processes which pollen grains may undergo prior to and during their sub-fossilisation may alter their physical appearance. These processes differ according to the circumstances and environment in which fossilisation takes place, and recognition of the resultant features may assist in the interpretation of a fossil pollen assemblage.

There is little known about the effects of taphonomic and depositional processes on the physical appearance of pollen grains although degraded pollen is often used as an interpretational tool (e.g. Cushing, 1964, 1966, 1967; Birks, 1970; Tolonen, 1980; Lowe, 1982; Tipping, 1984, 1987; Walker and Lowe, 1990) and assumptions are frequently made about the processes which have caused damage to pollen. Some experimentation has taken place in attempts to identify which processes cause which types of deterioration. Pollen grains stored in leaf mold may develop various features of corrosion due to bacterial attack (Havinga, 1964; Rowley *et al.*, 1990). Rowley *et al.* (1990) suggest that differences in the sporopollen content of grains can lead to differential preservation, as some grains are more resistant to attack than others. Similar conclusions were drawn by Sangster and Dale (1961, 1964) in experiments where different grains were buried in different natural environments and the rates and types of decay of the grains recorded.

Experiments by Holloway (1989) and Campbell and Campbell (1994) have shown that wet-dry cycles can have a considerable effect on pollen preservation, and may result in corrosion and thinning of the exine. It is often thought that the buffetting of pollen grains in coarse materials such as sand may also result in corrosion or at least breakage (Fall, 1987), but Campbell (1991) was unable to demonstrate this under laboratory conditions and concluded that wet/dry cycles are the most important contributors to pollen grain decay.

The different types of pollen exine deterioration have been identified (Havinga, 1964; Cushing, 1964, 1966; Tolonen, 1980). Most classifications follow that originally defined by Cushing (1964, 1966) and that used in this study, and defined below, is based on Cushing's deteriorated pollen types.

1. Degraded or thinned - exines appear altered as structural elements are fused together. The whole of the exine is affected.

2. Corroded or pitted - corrosion is characterized by random 'pits' over the surface of the grain which vary in size and coverage. Areas of the grain not pitted retain the normal characteristics of the pollen type.

3. Crumpled - grains are badly folded or wrinkled.

4. Broken - the exine is ruptured and the grain split. Occasionally only a proportion of the whole pollen grain will be present.

Some deteriorated pollen grains may be so badly affected that ascribing them to a pollen type is not possible. Although these grains are assigned to the 'indeterminate' category, this is subdivided into damage types as defined above. The type of damage, if any, for each grain identified was also recorded according to the above classifications.

Classification of deteriorated pollen grains is a subjective process (cf. Cushing, 1966; Lowe, 1982; Tipping, 1984). Some pollen types, including *Juniperus communis*, Poaceae and Cyperaceae crumple easily, and the breakage of saccate grains such as *Pinus*, where air sacs may become detached from the body of the grain, is common. The chemical procedures used in preparation of pollen samples may also affect the grains to some degree, and acetolysis may induce features akin to corrosion. These factors should be considered when interpreting damaged pollen data, and some damaged pollen types, such as crumpled Cyperaceae grains may be excluded.

Cushing (1966) has suggested a hierarchical classification system, whereby certain classes of deterioration take precedence over others. Whilst this avoids duplication of numbers of deteriorated pollen grains, this means that some types of deterioration will be under-represented (Lowe, 1982).

Despite the problems of subjectivity associated with deteriorated pollen classification, the recording of damaged pollen has been included in this study as it may be useful in the identification of re-worked sediments, changes in sedimentation and changes in pollen taphonomy. The damaged pollen classifications are given above in hiererarchical order, with 'thinned' as the most important and 'crumpled' the least important. Few degraded or thinned grains were recorded in the pollen counts and corrosion or pitting appeared to be the main component of the deteriorated grain assemblages. Crumpled and broken grains were also poorly represented, particularly as *Juniperus communis* and Cyperaceae were excluded from the crumpled category. Poaceae was recorded as crumpled when this was extreme and not a mere folding of the grain. *Pinus* grains were included in the broken category; grain bodies or grain bodies with one or more sacs were treated as a single grain. Single air sacs were recorded separately and 2 sacs were recorded as representing a single *Pinus* grain.

2.1.7.1 Presentation of damaged pollen data

The damaged pollen data are presented as percentages of raw counts of individual taxa, and total damaged pollen percentages of TLP (Lowe, 1982). Although damage types to which certain grains are particularly susceptible are excluded, the susceptibility of each type of grain to a particular type of damage may be considered when Total Damaged pollen percentages (TD%) are interpreted. Increases in damage to a single taxon might also indicate a different taphonomy for this pollen type, but large percentages of damaged pollen can occur due to the presence of very low amounts of a single taxon (e.g. a single pitted *Alnus* grain at one level will be represented as 100 % pitted). Damaged pollen is not represented as concentrations, as this would have the effect of increasing damaged pollen concentrations when taxon concentrations increase.

2.1.8 Dinoflagellate analysis

Dinoflagellate cyst analysis was undertaken by Dr. Rex Harland on sediments underlying AC1, AC2, LC1 and LC2 from Ulva. Minerogenic sediments sandwiched between organic material on cores LC1 and LC2 were also assessed for dinoflagellate content. The analysis was undertaken in an effort to determine whether the sediments originated from the erosion of terrestrial surfaces in the Lateglacial, or were deposited in marine conditions in the early Holocene.

A total of 23 samples were processed using palynological procedures outlined by Wood *et al.*, (1996) although oxidising agents were avoided in order to prevent the loss of delicate cysts (Harland, 1998). In order to allow the calculation of the number of cysts per gramme of sediment, the dry weight of each sample was noted and aliquot samples of the organic residues were taken after acid digestion, mounted in Elvacite, and counted using a x10 objective (Harland 1989, 1998).

2.1.9 Sample treatment and laboratory methods

Volumetric samples of 1cm^3 were processed for analysis of pollen content. Sampling intervals vary from 4 cm down to 1 cm contiguous samples and the refinement of sampling resolution was undertaken after initial pollen counts were achieved. Refinements targetted observed changes in the pollen spectra which were of ecological interest and where the possibility of human impact was considered likely.

All samples were suspended in HCl, followed by 10 % KOH and acetolysis treatment (Faegri and Iversen, 1989; Moore *et al.*, 1991). Samples from lake sediments and peat from the base of profiles containing particles of silica were boiled in 40 % HF for 20 minutes. Tablets of *Lycopodium clavatum* spores were added to each preparation to allow the calculation of pollen concentrations (Stockmarr, 1971).

Slides were prepared from processed samples and viewed under a light microscope at a magnification of x400. Individual grains requiring greater attention for identification were viewed at x1000 with the slide under oil immersion.

Pollen from Loch a'Bhogaidh and Farm Fields, Rum, was counted to a minimum of 500 total land pollen (TLP) (i.e. excluding aquatics and spores) where concentrations allowed. Low concentrations in some sections of the Loch a'Bhogaidh cores meant that counts of some samples reached only c. 300 land pollen (although spores were numerous). Pollen counts from Ulva were based on a land pollen count of at least 300, but *Alnus* was excluded due to its extreme abundance. However, most of the levels counted exceed 500 land pollen. Identifications of fossil pollen and spores were based on the type slide collection of the Department of Archaeology and Prehistory, University of Sheffield, aided by the keys, *inter alia,* of Birks (1973), Faegri and Iversen (1989) and Moore *et al.*, (1991). Pollen and spore type nomenclature follows Bennett (1994) and Bennett *et al.*, 1994).

2.1.10 Loss on ignition (LOI)

All levels sampled for pollen and some from non-polleniferous material in the Ulva cores were measured for percentage organic content by loss on ignition (LOI). Samples of 1cm^3 were dried for at least 12 h at 105°C in crucibles of known weight. These were then weighed and ignited at 500°C for 3 h. Ash weights were recorded and organic content calculated and expressed as a percentage of dry weight (Bengtsell and Enell, 1986).

2.1.11 Construction of pollen diagrams

All pollen diagrams were constructed using TILIA 2 spreadsheets and TILIA.GRAPH 2 (Grimm, 1991) and zoned with the aid of CONISS.

Percentages are based on TLP. Detrended correspondance analysis (Decorana [Hill, 1979]) of taxon variables from individual cores, and of zone mean scores, was also undertaken using the ordination routine of TILIA.

2.2 Choice of sites

Most of the sites chosen for coring as part of this study are close to known areas of Mesolithic and Neolithic occupation (Armit, 1996). These are Loch a'Bhogaidh on Islay, Farm Fields at Kinloch, Rum and A'Chrannag and Livingstone's Cave bogs on Ulva (Figure 2.1).

Pollen analyses of two cores from Loch a'Bhogaidh had already produced profiles which suggest human impact on vegetation in the Mesolithic (Edwards and Berridge, 1994; Edwards and Mithen, 1995), and additional cores were obtained for closer resolution sampling in order to provide greater spatial and temporal detail on the original interpretations, and in an attempt to detect smaller scale changes which could not be perceived in the original cores.

The proximity of A'Chrannag and Livingstone's Cave bogs on Ulva to the midden deposits at Livingstone's Cave (Bonsall *et al.* 1991, 1995) suggested that the detection of disturbance in the pollen record relating to the occupation of the cave was likely. Both Mesolithic and Neolithic people may have altered vegetation near the site as the archaeological remains extend into the latter period according to finds and radiocarbon dates (*ibid*). No pollen data from Ulva are currently published, and palynological investigations from these sites was anticipated to be useful in completing the Holocene pollen record for the Inner Hebrides. The small area of the island (approx. 28 km^2) could produce vegetation types and successions different from those of the larger islands during the Holocene.

The island of Mull was included in this study as it was anticipated that pollen profiles may provide suggestions of Mesolithic activity in the absence of archaeological evidence (the midden at Dervaig [Robins, 1998] was not known and was unpublished when fieldwork was undertaken). Sites originally cored by Lowe and Walker (1986a and b) and Walker and Lowe (1985, 1987) were considered for additional coring. A peat-filled depression at Gribun, western Mull and Loch an t'Suidhe on the Ross of Mull were assessed as offering the greatest potential for providing a complete early Holocene pollen record. These sites also followed a north-south transect from Ulva, both being on the western side of the island. Unfortunately, pollen from Gribun proved too sparse to provide a useful record, and the core from Loch an t'Suidhe near Bunessan (Lowe and Walker, 1986a and b) is the only one from Mull to be included in the project. Loch an t'Suidhe is small, thus multiple coring was considered inappropriate. However, close resolution sampling was intended to provide greater detail for the early Holocene part of the core.

The pollen from a single core from Farm Fields, Kinloch, Rum was also suggestive of Mesolithic impacts, and occurrences of cereal-type pollen in combination with radiocarbon dates show that agricultural practices may have occurred here early in the Neolithic from c. 3950 BP (2540 cal. BC) (Hirons and Edwards, 1990). Further profiles obtained from the Farm Fields sites were intended to provide greater spatial and temporal detail for these events, but the recovered peat monoliths proved unable to provide a pollen record covering the

Mesolithic. Thus, the focus of investigation on Rum was restricted to the detection of the earliest cereal cultivation in the pollen records.

2.3 Coring

Coring was carried out at Loch a'Bhogaidh, Islay, A'Chrannag and Livingstone's Cave bogs, Ulva, and at Loch an t'Suidhe, Mull using a wide bore (8 cm diameter) Russian-type corer (Jowsey, 1966) where possible. A small bore (5 cm diameter) corer of similar type was used for very deep sediments at Loch a'Bhogaidh and on Ulva where extraction with the larger device was otherwise impossible. Due to the shallow depth of the peat on Rum, pits were dug and all samples obtained in monolith tins from a cleaned peat face.

A general survey of surface vegetation was undertaken for each site and samples obtained at the surface of each core and other strategic places. Site descriptions appear in chapters 3 - 6.

CHAPTER 3 - LOCH A'BHOGAIDH, ISLAY. Discussion and interpretation of multiple profiles from lake sediments

3.1 Site location and description

Loch a'Bhogaidh (Figs. 3.1a and b; Plates 3.1 and 3.2), NGR NR 224 577, is an area of fen peat surrounded by blanket peat of dimensions 500 m north-south and 350 m east-west. It lies approximately 500 m to the east of Beinn Tart a'Mhill on the Rhinns peninsula. The archaeological sites of Bolsay and Gleann Mor are located 500 m south and 1050 m northeast of the mire respectively. The bog is surrounded to the north and east by low gentle slopes dominated by *Pteridium aquilinum.* Elsewhere the mire becomes drier and extends into *Calluna vulgaris* heath. *Betula-Corylus* woodland is located to the west of the site in a sheltered valley at the foot of Beinn Tart a'Mhill.

The surface of Loch a'Bhogaidh contains areas of open water surrounded by *Phragmites australis.* Thickets of *Salix* spp. and *Rubus* spp. agg. are common although the majority of the bog surface supports hummocks of *Molinia* sp. and *Eriophorum angustifolium* interspersed with *Sphagnum* spp. pools. Other common bog plants include *Myrica gale, Succisa pratensis, Parnassia palustris* and *Hypericum elodes.*

The current peat surface overlies an expanse of gyttja or organic lake sediment and an east-west transect by Agnew *et al.* (1988) shows the depths of gyttja and overlying peat and basal deposits of pink clay which are probably of Lateglacial origin (Fig. 3.2).

3.2 Background to the current project

Cores LABI (NR 2243 5782), LABII (NR 2260 5745) (Edwards and Berridge, 1994) and LABX (NR 2254 5805) (Agnew *et al.*, 1988) have already been used in the reconstruction of vegetation at Loch a'Bhogaidh. These have been included in a general vegetation history for Islay in Section 1.3.1. As LABX post-dates the *Alnus* rise (Agnew *et al.*, 1988) it is not comparable with the other early Holocene profiles. LABII appears to exhibit a substantial hiatus in sedimentation and is not radiocarbon-dated (Edwards and Berridge, 1994), but is nevertheless useful in the interpretation of multiple profile pollen studies at the site.

Six further cores were obtained for the purposes of this study, LABIII (NR 2236 5792), LABIV (NR 2245 5771), LABV (NR 2232 5777), LABVI (NR 2257 5777), LABVII (NR 2240 5776) and LABVIII (NR 2235 5782). Cores LABIII, LABVII, LABI, LABIV and LABII are located at intervals along the north-south axis of the mire (Fig. 3.1), and although these are not on a linear transect line the accumulated lithologies provide an indication of the north-south stratigraphy of the site (Fig. 3.3). Obtaining cores from a north-south transect was hampered by surface vegetation which included dense thickets of *Salix* and *Rubus* spp. agg., deep pools of open water dominated by *Phragmites australis* to the southwest, and sub-surface accumulations of gravel.

3.3 The possible extent of the earlier loch

The eastern edge of the mire is bounded by a sharp break of slope (indicated by the 70 m contour line in Figure 3.1b). The west of the mire rises more gently, and the drier ground is colonised by *Calluna vulgaris* and other ericaceous taxa. The extent of the loch in the early Holocene was therefore limited by slopes to the east, and the southeasterly profile LABVI is probably located close to the loch's eastern margin.

The east-west profile (Fig 3.2; Agnew *et al.*, 1988) indicates that in the shallower sediments, thin basal deposits of gyttja are overlain by clay, and are lithologically similar to the LABII profile. As LABII may indicate the southerly limit of the loch in the early Holocene (Edwards and Berridge, 1994) then similar profiles to the west of the site may delineate its former extent in that direction.

Although the stratigraphic transect of the north-south profile is incomplete, the basin appears to have had a smoother and more uniform topography. If the depth of gyttja is a reflection of water depth, it appears that a deeper basin of water occurred to the north and an elongated area of shallow water extended to the south as indicated by the lithologies of LABIII, LABVII, LABIV and LABII (Fig. 3.3).

3.4 The pollen diagrams

Percentage pollen diagrams for LABI - LABVIII comprise Figures 3.4 - 3.11. Summary diagrams of LOI, charcoal concentrations, influx and Ch:P, TLP concentration and influx and total damaged pollen percentages for LABI - LABVIII are shown as figures 3.12 - 3.19. Concentration diagrams for selected taxa from the profiles are presented in Figures 3.20 - 3.27 and pollen influx diagrams in 3.28 - 3.35. Figure 3.36 shows the *Corylus* percentage curves for profiles LABI and LABIII - VIII plotted against age, and Figure 3.37 the influx curves for the same profiles (LABII was excluded in view of the absence of dates on the profile and difficulties of comparison with other cores). Figure 3.38, 3.39 and 3.40 respectively display the charcoal concentration, influx and Ch:P data for all profiles except LABII, and TLP concentrations and influx rates for profiles LABI and LABIII - LABVIII are presented as Figures 3.41 and 3.42. It should be noted that where AMS dates are used in extrapolation, some dates on LABVIII are acquired from comparison with other profiles. Damaged pollen percentages for selected taxa from each profile LABIII - LABVIII are shown in figures 3.43 - 3.48.

Scanning and low pollen counts from samples preceding the levels displayed in the diagrams (from earlier gyttja and clays) showed that *Betula* and *Myriophyllum alterniflorum* dominated the pollen assemblages and the earliest *Corylus* pollen detected is displayed on all the profiles.

Sampling intervals are refined to 1cm contiguous samples for the *Corylus* rise and expansion, and where reductions in the *Corylus* curve became evident. Wider sampling intervals occur elsewhere. Pollen counting was hampered in some of the profiles by very low pollen concentrations or the absence of quantities of organic material after processing. Such levels were sampled more than once to ensure that chemical processing was not responsible. The absence of pollen in some sampled levels, and very low pollen counts in others, means that in some places in the diagrams there are uneven sampling intervals and wider than intended sampling resolution.

Comparisons between diagrams have been drawn on the basis of the percentage pollen profiles aided by reference to the concentration data (Table 3.1). AMS dates were also used as a guide for comparisons, but where pollen percentage data showed strong similarities but dates between profiles conflicted, reliance was placed on the percentage data (refer to Section 3.4). A DCA plot of post-hazel rise mean scores (Fig. 3.49a) and one of zones c and d (Fig. 3.49b) were also used to assist in the comparison of zones and subzones between profiles.

3.5 AMS dates on the Loch a'Bhogaidh profiles

3.5.1 LABI

Six radiocarbon dates were obtained for core LABI (Table 3.2) by Edwards and Berridge (1994) but only three of these relate to the first half of the Holocene. These dates were obtained from conventional radiocarbon analyses of 10cm thick portions of core, which makes it difficult to ascribe a precise date to the centre of each sample. Therefore these dates may therefore not be as reliable as the AMS dates determined for smaller volumes of sediment restricted to 1cm depth. Nevertheless, other than the basal determination, they seem to provide an adequate timescale for vegetation changes as reflected by the pollen from the Loch a' Bhogaidh catchment. The basal date on LABI may be erroneous due to laboratory error or an inadequate carbon content for the sample.

3.5.2 LABIII - LABVIII

Twenty three AMS dates were obtained for cores LABIII to LABVIII (Table 3.3; Fig. 3.50). These were intended to allow comparison between cores from Loch a'Bhogaidh and elsewhere in the Inner Hebrides, but specific features on the percentage pollen diagrams which may represent climatic and natural ecological changes or human impact were also targeted.

3.5.3 The early hazel peak, LABIb(i), 10910±450 BP (10,740 cal. BC)

Comparison of the earliest date on LABI to other pollen profiles from the Inner Hebrides and western Scotland suggests that on the basis of initial increases in *Corylus avellana*-type pollen the date of 10,910±450 BP (10,470 cal. BC) (Edwards and Berridge, 1994; Sugden and Edwards, in press) is too old even if the standard deviation is not ignored. Edwards and Berridge (1994) note that the range of pollen of thermophilous taxa which occurs in LABIb(i) includes *Corylus avellana*-type, *Juniperus communis, Empetrum* and *Betula.* These reflect temperate conditions yet dates of c.10,910 BP (10,740 cal. BC) for other sites in the Inner Hebrides suggest Lateglacial Loch Lomond Interstadial conditions (e.g. Birks, 1973; Birks and Williams, 1977; Lowe and Walker, 1986; Walker and Lowe, 1985, 1987). The preceeding clay lithology incorporating the pollen of Poaceae, Cyperaceae and a variety of herbs on LABIa(i) and a(ii) are more representive ofLateglacial tundra conditions (Edwards and Berridge, 1994) and an older date. Indeed, the mixing of earlier sediments with later gyttja may explain the anomalous date at the base of LABIb(i) if low carbon levels or laboratory error are not the cause.

Comparison of LABI with the other pollen profiles from Loch a'Bhogaidh also confirms the above anomaly. Expansions of *Corylus avellana*-type pollen appear much later than 10910 ± 450 BP (10, 740 cal. BC) in the additional profiles (i.e. c. 9500 BP; 9615 ± 65 (8990 cal. BC) on LABVIIa; 9415 ± 65 (8800 cal. BC) on LABIIIa; 9565 ± 75 (8930 cal. BC) LABIVa). Pollen data from Arran (hazel rise c. 9500 BP (8900 cal. BC), Robinson and Dickson, 1988; Edwards, 1990), the mainland (hazel rise 9230 ± 120 BP (8500 cal. BC); Peglar 1977 in Birks, 1980; Boyd and Dickson, 1988) and other Inner Hebridean islands (eg. Skye, Birks and Williams, 1983; Walker and Lowe, 1991a, and Mull, Lowe and Walker, 1985) also suggest that the *Corylus* expansion at LABI should be later.

3.5.4 LABIIIc

There are three dates in LABIIIc (8215 ± 80 BP (7290 cal. BC); 7720 ± 70 BP (6600 cal. BC) and 7710 ± 100 BP (6570 cal. BC)) which do not correlate with dates on the other profiles (including interpolated dates) for what are considered to be related zones. LABIIIc displays a distinctive reduction in *Corylus* with accompanying changes in other taxa and increases in TD%. This reduction and associated characteristics also appear in LABIVc and LABVIc, LABVIIc and LABVIIIc, and in LABIc between the depths of 650 cm and 620 cm. The DCA plots of zone mean scores (Fig. 3.40a and b) indicate that LABIIIc compares well with LABIVc, LABVIc, and LABVIIIc on the DCA1 axis on both charts. Comparisons of all profiles suggest that this *Corylus* reduction begins c. 7700 BP (6600 cal. BC), making the earliest date at the base of LABIIIc too old. This date overlaps at two standard deviations with the later date for this zone (Fig. 3.50b), and may represent a period of rapid sedimentation due to erosion. LABIII is located close to a stream at present and may also have been close to a stream inlet at the loch edge in the early Holocene. LABIIIc may therefore incorporate re-worked material, indicated by a change in lithology, which has made the dates older. There is no other evidence of erosion as LOI does not decrease but older organic material may have been introduced by a slow-flowing stream, such as that which currently crosses the mire. Anomalies in the dates in LABIII may also have arisen from the accidental incorporation of older carbon to the sample in the field or laboratory.

3.5.5 Extrapolation of age-depth curves and pollen influx calculation

Linear extrapolation between the AMS dates on the profiles was used to provide age-depth curves (Figs. 3.51 - 3.57) and to calculate pollen influx rates and sediment deposition times. Where only one or two dates were available on a profile (e.g. LABV and LABVIII) additional dates were estimated by comparing dated features common to all the profiles. This was to allow the visual comparison of pollen and microscopic charcoal data for the complete suite of profiles, and it is appreciated that further radiocarbon dates are required on these profiles to firm the conclusions presented later.

Given the likelihood that certain dates on LABI and LABIII are too old, two sets of age-depth curves were calculated for these profiles, the first using the actual dates acquired, and the second using dates inferred by comparison with the other profiles. The DCA plot of zone mean scores Fig. 3.40a indicates that LABIb(ii) compares well with zone a for the other profiles, where the *Corylus* rise occurs dating to c. 9700 BP (9040 cal. BC). The earlier LABIb(i) is seperated from these and this may reflect the different pollen assemblage and earlier date. Thus, a second age-depth curve for LABI is suggested using 9700 BP (9040 cal. BC) at the second *Corylus* rise on the profile and omitting the earlier date of 10,910±450 BP (10,740 cal. BC).

As the DCA plots (Fig. 3.49a and b) indicate that dates on LABIIIc should be later, a second age-depth curve has also been estimated for this profile for ease of comparison with other profiles. The second profile with assumed dates used 7700 BP (6600 cal. BC) as the basal date for the *Corylus* reduction and 7100 BP (5930 cal . BC) as the date for the *Corylus* recovery, although given variation in dates on the other profiles the true dates could fall within this range, if the original dates are indeed incorrect.

3.6 Isoetes lacustris spores as an indicator of erosion

Microspores of the submerged aquatic *Isoetes lacustris* are prominent in most of the pollen diagrams from the site. Vuorela (1980) has suggested that increases in the microspores of *Isoetes lacustris* in pollen diagrams from lake sediments may be representative of short erosive episodes linked to agriculture. Gacia and Ballesteros (1994) showed that although light levels and temperatures affect the growth and productivity of *Isoetes lacustris* spores, the primary limiting factor is nutrient availability. Vuorela (1980) also suggested that increases in mineral input to a lake will increase nutrient availability and favour the expansion of communities of *Isoetes lacustris*, although eventual eutrophication due to lengthy periods of erosion will significantly deplete populations. A short-lived pre-agricultural disturbance in a lake catchment should therefore produce temporary increases in *Isoetes lacustris* in the pollen record. Where there are also reductions in LOI, the indication is that some disturbance to vegetation within a pollen catchment has occurred (Vuorela, 1980).

Szmeja (1994) showed that *Isoetes lacustris* communities favour lakes or pools with slow sedimentation rates and an input of fine detritus, and these conditions are unlikely to occur for any length of time when minerogenic input is increased. Although the abundance of damaged *Isoetes lacustris* microspores was not quantified, owing to the prohibitatively great abundance of counts for this taxon, it was observed that many, perhaps 70 % or more, of the exines were split or broken. Whilst breakage may be an intrinsic characteristic of this type of spore due to its flimsy perine, the re-working of spores in usual lake sediment focusing or during erosional periods could increase breakage.

Whilst water levels at Loch a'Bhogaidh are unknown, and will have changed through time, *Isoetes lacustris* may have been absent from the central basin due to lower light levels and temperatures if the loch waters were particularly deep (Gacia and Ballesteros, 1994). The *Isoetes lacustris* microspores in LABI, LABVII and LABVIII could therefore be reworked. In LABI and LABVII, *Isoetes* microspores are present at every level from *c.* 9000 BP (8225 BC) and reach values of between 150 - 200 % TLP. In LABVIII *Isoetes lacustris* microspores expand later c. 8000 BP (6860 BC) (LABVIIIb) and display a uniform and uninterupted curve reaching values of c. 750 % TLP. Profiles from the outlying cores LABII, LABIII, LABIV, LABV and LABVI show comparitively low levels of *Isoetes lacustris* microspores c. 10 % TLP, but there are sporadic increases which at times reach > 1500 % TLP in LABIV and LABV.

All the major increases in *Isoetes lacustris* in the outlying cores coincide with reductions in LOI, and frequently with reductions in other taxa, and increases in TD%. Although *Isoetes lacustris* may have been more abundant in the shallow waters of the loch edge, the increases in its spores may signify disturbances to vegetation in the loch catchment, particularly when these occur in conjunction with other significant data. Increases in *Isoetes lacustris* may arise due to natural disturbances or human impact causing erosion into the loch.

3.7 Damaged pollen analysis

Damaged pollen was assessed for profiles LABIII - LABVIII as detailed in Section 2.1.5. It was noted in pollen counting that most of the damaged pollen was pitted. Differences in percentages of damaged pollen for individual taxa within profiles are not extreme, and between profiles TD% is consistently between 20 - 30 % except in LABIII where for most of the profile damaged pollen percentages are lower, at around 10 % TLP. This suggests that a constant proportion of pollen is damaged by taphonomic processes and pollen in LABIII may be better preserved due to a lower influx of re-worked pollen from sediment focusing.

Increases in TD% occur in LABIIIc which could reflect an increase in re-worked pollen, either from the loch sediments or from the surrounding catchments . Slight increases in TD% occur in LABIVc, LABVIc and LABVd and may be linked to erosion due to woodland reduction in these zones.

3.8 General representations of the pollen profiles

Pollen profile LABI (Edwards and Berridge, 1994) is the most central of all the cores from the site, and is thus likely to provide a broader and more regional representation of vegetation than the other profiles. The outlying cores were intended to provide details of very local disturbances and changes in vegetation. A comparison of zones between profiles is provided in Table 3.1. Despite evident differences between profiles, the general vegetation history of Loch a'Bhogaidh remains similar in all the cores. *Betula*, Poaceae and Cyperaceae comprise the main early Holocene assemblage, then *Corylus avellana*-type rises rapidly to become the dominant taxon for the remainder of the profiles. Other arboreal taxa present from c. 9000 BP (8225 cal. BC) include *Ulmus* and

Quercus, taxa frequently associated with *Corylus* and components of contemporary *Corylus* woodlands in the Inner Hebrides (Birks, 1983; Lowe and Walker, 1986a and b). A tall-herb understorey is suggested by the presence of *Filipendula*, Apiaceae and *Rumex* spp., and the spores of *Polypodium vulgare*-type and Pteropsida (monolete) indet. (ferns) reflect the damp shady environment of the woodland floor. Aquatic taxa are few with the exception of *Isoetes lacustris.*

3.8.1 Pollen concentration and influx

In chapter 2 it was explained that spatial differences in pollen recruitment and the effects of sediment focusing within a lake basin could result in differences between pollen profiles, and that variability in sediment accumulation within different parts of a lake basin should be apparent in the pollen concentrations and pollen influx curves of multiple profiles.

Calculations of total pollen concentrations and influx rates (Figs. 3.41 and 3.42) incorporate only land pollen, as the large amounts of the spores of *Isoetes lacustris,* which are either consistent or sporadically apparent in all the profiles, have a marked influence on the overall concentration and accumulation data curve.

It is noted that the comparison of absolute values for LABI and LABII with those from the other profiles may not be satisfactory, as lower TLP counts and the differing number of exotic spores added to the sample preparations will compound statistical errors inherent in the calculation of such values (Section 3.7.1.2).

Low pollen concentrations in the early Holocene, (LABIb, LABIIb, LABIIIa, LABIVa, LABVa, LABVIa, LABVIIa and LABVIIIa [Figs. 3.20 - 3.27; Fig. 3.41]) are probably linked to fast sediment accumlation rates. The rise of *Corylus* coincides with an expansion of TLP concentrations which average c. 100,000 grains cm^{-3} in LABIIIb(i) and (ii), LABIVb(i), LABVb(i) and LABVIb, LABVIIb(i) and (ii) and in LABVIIIb. The equivalent portion of LABIc(i) displays lower concentrations of c. 50,000 grains cm^{-3}. As the most central of the profiles, LABI may have received lower amounts of pollen (cf Davis and Brubaker, 1973), particularly in the early Holocene, when trees were few and the flora was dominated by Poaceae and Cyperaceae whose pollen has a limited range of distribution compared to tree pollen. However, similar low concentrations of *Corylus* in LABIId(i) suggest that anomalous *Corylus* concentrations in LABI and LABII are recorded compared with the subsequently sampled profiles, possibly due to statistical Inaccuracies derived from the estimation of pollen concentrations. Nevertheless, the shapes of the TLP concentration curves between all the profiles (Fig. 3.41) are similar although average concentrations range from 50,000 to > 300,000 grains cm^{-3} for all the profiles.

TLP concentrations are greater in LABVII and LABVI (Fig. 3.41). LABVII may be expected to recruit greater amounts of pollen than elsewhere as it was placed in profundal sediments which derive pollen from the loch perimeter and receive large amounts of airborne pollen. High amounts of TLP concentrations in LABVI of between c. 200,000 - >300,000 grains cm^{-3} contrast with average concentrations of c. 100,000 grains cm^{-3} in the other peripheral profiles. These may be explained if wind and wave direction transported pollen to the southwestern area of the loch, but low sediment accumulation rates at LABVI (0.0125 cm yr^{-1}; Fig. 3.17) may also account for high TLP concentrations.

Attention has been paid to *Pinus* pollen concentrations as this pollen is particularly buoyant and more susceptible than other grains to the action of wind and waves. Thus, variable concentrations of *Pinus* pollen between profiles may assist in explaining different concentrations of other pollen types and microscopic charcoal which may also be particularly prone to focusing by wind and wave action. *Pinus* concentrations in the deeper central profiles LABI, LABVII and LABVIII average c. 5000 grains cm^{-3} (Figs. 3.20, 3.26, 3.27). In LABII, LABIII and LABV *Pinus* concentrations average c. 2500 grains cm^{-3} (Figs. 3.21, 3.22, 3.24) and LABIV and LABVI *Pinus* concentrations compare with the central profiles at c. 5000 grains cm^{-3}(Fig. 3.23 and Fig. 3.25). Pennington (1949) suggests that the air sacs on *Pinus* grains may fill with water and rapidly sink, which could explain greater amounts of *Pinus* pollen in profundal lake sediments. The greater concentrations in the peripheral profiles to the south-west of the loch basin may be the result of wind direction, but more probably the slower sediment accumulation rates at LABIV and LABVI (c. 0.0125 cm yr^{-1}; Figs. 3.15 and 3.17) compared with the other peripheral profiles (c. 0.33 cm yr^{-1}; Figs. 3.13, 3.14, 3.16) are responsible. There is therefore no evidence from the Loch a'Bhogaidh profiles to suggest that wind and wave direction significantly affected pollen distribution over other process such as sediment focusing.

When plotted against depth, the pollen influx data from Loch a'Bhogaidh (Figs. 3.21 - 3.27) closely mirror the concentration data. Variations in sediment deposition rates coincide with expected changes in pollen influx within each profile, as calculation of both is affected by the specific location of dates on the profiles. For all the profiles, *Corylus* experiences the highest influx rates, particularly in the earlier Holocene. When plotted against age (^{14}C yr. BP) it is noticeable that the perimeter profiles LABIII, LABIV, LABV and LABVI have lower TLP influx (average c. 2500 grains cm^{-2} yr^{-1}) than LABVII, LABVIII and LABI (average c. 5000 - > 20,000 grains cm^{-2} yr^{-1}) (Fig. 3.42). Influx values for individual taxa, especially *Betula, Ulmus and Quercus*, are also greater in the deeper profiles LABI, LABVII and LABVIII (Figs. 3.28 - 3.35). As sediment deposition is faster in the deeper cores at c. 0.05 cm yr^{-1} (compared to c. 0.016 cm yr^{-1} in peripheral cores) (Figs. 3.12 - 3.19), then it could be expected that pollen influx should be lower, there being less time for pollen to become incorporated into the sediment. However, if the sediment of the profundal profiles was largely derived from material focused from the loch perimeter then some of the material (including pollen) from the outlying regions of the loch may have been removed and focused into the areas where greater depths of gyttja now exist. Very high TLP influx for LABVII (> 20,000 grains cm^{-2} yr^{-1}) suggests that this part of the loch received the bulk of sediment transported in from the perimeter.

Most of the pollen influx profiles from Loch a'Bhogaidh show no marked changes through time. However, between c. 7900 BP (6810 cal. BC) and 7700 BP (6600 cal. BC) pollen influx rates at LABVII increase markedly, influenced mainly by the *Corylus* influx curve. After c. 7700 BP (6600 cal. BC), pollen influx at LABVII remains higher, (> 20,000 grains cm^{-2} yr^{-1})than in the other profiles. *Corylus* accumulation rates thus increase over this time from c.10,000 to 25,000 grains cm^{-2} yr^{-1} and sedimentation from 13 to 5 yr cm^{-1}. This suggests that from this time the main site of sediment focusing in the loch was in the region of LABVII.

3.8.2 Microscopic charcoal concentrations and influx

Microscopic charcoal curves (including concentrations, Ch:P and charcoal influx) are presented against depth for each profile in Figures 3.12 - 3.19 and in composite diagrams in Figures 3.38 - 3.40. For individual profiles, the three different representations of microscopic charcoal show similar patterns, with reductions and increases occurring simultaneously within the curves. The mode of charcoal representation does not appear therefore to be significant (cf Edwards and Whittington, in press) and where reference is made to Ch:P in the following interpretation, changes in absolute charcoal values may also be assumed.

The microscopic charcoal influx curves show a similar pattern to that of the TLP influx curves (Fig. 3.42), in that the central profiles LABVII, LABVIII and the new charcoal samples for LABI incorporate greater amounts of microscopic charcoal than the peripheral profiles. (The original LABI charcoal concentrations and influx are not comparable due to reasons mentioned earlier in 3.6.1 and different methods of microscopic charcoal quantification. Edwards and Berridge (1994) used point count estimation). The greater amounts of microscopic charcoal in centrally positioned profiles could be explained by their greater potential for the receipt of airborne particulates and mechanism of sediment focusing mentioned above. It is also possible that the peripheral profiles could have received greater amounts of stream-borne pollen and microscopic charcoal, this method of transport and deposition effectively diluting pollen and charcoal influx.

The composite charcoal influx diagram (Fig. 3.40) shows that relatively high charcoal influx rates occurred in the early Holocene at the base of the profiles between c. 9700 BP (9300 cal. BC) until c. 9000 BP (8180 cal. BC) although influx is relatively low in LABV and LABIV despite correspondingly high concentrations and Ch:P at this time in these two profiles (Figs. 3.38 and 3.39). Later in all the profiles, between c. 7700 BP (6660 cal. BC) and 7100 BP (5930 cal. BC) substantial increases in charcoal influx are evident in LABVII and LABVIII. LABV, LABIV and LABVI also show slight increases in charcoal influx, although overall charcoal influx rates are much lower in these profiles (Fig. 3.40).

High charcoal influx in the early Loch a'Bhogaidh profiles may derive from the receipt of high levels of airborne charcoal from a wide area in a relatively open environment. A greater input of eroded material may also have assisted in increasing charcoal influx. Later in the Holocene the expanding areas of *Corylus* dominated woodland may have intercepted airborne charcoal, and stabilised soils thereby reducing erosion. Charcoal influx may be persistently higher in the profundal profiles as these could have had greater exposure to the fallout of airborne charcoal. Streams feeding into the loch edge may have diluted charcoal influx in the peripheral profiles, and sediment focusing to the loch centre may also have deprived the edge profiles of charcoal. Temporary increases in charcoal influx in the profiles, particularly in the peripheral profiles, often correlate with reductions in woodland at the loch edge which may have increased the amounts of airborne or eroded charcoal reaching the site. Charcoal increases may also derive from fires at the loch edge, either natural or anthropogenic in origin.

3.9 Interpretation of the profiles

3.9.1 LABIa(i) and LABIa(ii) Cyperaceae - *Cichorium*; LABIIb Cyperaceae - Asteraceae - Caryophyllaceae (Pre c. 10,000 BP [9400 cal. BC])

These zones are earlier than those recorded in the other profiles, and the pollen record extends into the clay underlying the gyttja. Poaceae, Cyperaceae, *Empetrum* and tall-herbs dominate the pollen assemblages reflecting an open environment. Small amounts of *Betula* pollen suggest that birch scrub or copses of birch were locally present, although the pollen may derive from *Betula nana*. *Pinus* pollen is also present and the later introduction of *Corylus* in the following zone suggests that LABIa(i) and a(ii) represent a tundra-like environment immediately preceding climatic amelioration of the early Holocene (Edwards and Berridge, 1994).

3.9.2 LABIb(i) and LABIb(ii) *Betula* - Poaceae - Cyperaceae; LABIIc *Betula* - Poaceae, LABIIIa *Betula* - Poaceae - Cyperaceae; LABIVa *Betula* - Poaceae - Cyperaceae - *Filipendula*; LABVa *Betula* - Poaceae - Cyperaceae; LABVIa *Betula* - Poaceae - Cyperaceae - *Filipendula*; LABVIIa, *Betula* - Poaceae - Cyperaceae; LABVIIIa *Betula* - Poaceae - Cyperaceae; (c. 10,000 - 9300 BP [9400 - 8540 cal. BC])

LABIb(i) and LABIb(ii) displays a pollen assemblage similar to the earlier (sub)zones of LABIa, LABIb(i) and LABIIb and include *Betula*, *Empetrum*, Poaceae and Cyperaceae. Herbs include Lactuceae, *Filipendula*, *Plantago* spp. and *Rumex acetosa* representing a tall-herb flora characteristic of other early

Holocene environments in the Inner Hebrides (e.g. Mull - Walker and Lowe, 1985, 1987; Lowe and Walker, 1986a; Skye - Birks, 1973). A similar flora to those in LABIb and LABIIb is recorded in the other profiles, although percentage values may differ, and the minor taxa vary in frequency.

The initial expansion of *Corylus* is recorded in all the profiles. In LABVIIa *Corylus* increases above 2% TLP at 9615 ± 65 BP (8990 cal.BC). In LABIVa *Corylus* is present in the early part of the zone at values < 2 % but this is possibly the result of the reworking of penecontemporaneous sediments or pollen. Higher percentages, concentrations and influx occur in the latter part of LABIVa, and the first *Corylus* record > 2 % dates to 9565 ± 75 BP (8930 cal. BC). Extrapolation of dates for LABVIIIa, LABIIIa, LABVa and LABVIa places the initial expansion of *Corylus* at c. 9500 BP (9400 cal. BC). The hazel rise at LABIb(i) has an estimated date of c. 10,000 BP (9400 cal. BC) and the second rise in LABIb(ii) is estimated at c. 9500 BP (9400 cal. BC) as mentioned in Section 3.4.3.3.

LABVIIa displays higher *Corylus* percentages than the other profiles and is the profile most similar to LABIb(i) and b(ii). The rise of *Corylus avellana*-type pollen in LABIb(i) and b(ii) shows distinct fluctuations which are defined by these subzones. LABIb(i) does not appear to be distinguished in concentration terms for individual taxa, and does not feature in the TLP concentration curve. It is thus interpreted as an artefact of the percentage data (Edwards and Berridge, 1994; Edwards and Mithen, 1995). LABIb(ii) appears as a distinct subzone in the concentration data and this suggests that a real decline in *Corylus avellana*-type pollen occurred. The pattern in the early *Corylus* curve is replicated over a shorter depth in percentage terms in LABVIIa although less clearly in the concentrations.

For LABVIIa, the peak in *Corylus* prior to its second reduction dates to c. 9400 BP (8670 cal. BC). At similar times in LABIVa and LABVa, the *Corylus* percentage profiles display single level reductions although these do not appear in the LABVa concentrations, and LABIIIa and LABVIa show a rapid rise in each *Corylus* curve with no distinct fluctuations. LABVIIIa displays *Corylus* percentages and concentrations prior to c. 9300 BP (8540 cal. BC) which are too low to reliably detect any fluctuations. It is probable that the poorer resolution of LABIII, LABIV, LABV and LABVI means that any fluctuations in the early *Corylus* populations have not been detected.

High values of Ch:P are also a feature of LABIIIa - LABVIIIa, LABIb and LABIIc, but these are probably a function of low pollen influx rates and charcoal influx is probably a more reliable indication of amounts of charcoal present in these zones. Charcoal influx is greatest in LABIb (~ 1000 cm^{-2} cm^{-3} yr^{-1}) and is high in LABVIIIa (~ 250 cm^{-2} cm^{-3} yr^{-1}) but it is lower in the other profiles (Fig. 3.40). The much higher influx values in LABIb could result from its central location and could therefore indicate that most of the charcoal received was of aerial derivation.

LABIb displays greater pollen influx rates than comparable zones in the other profiles including LABVIIa and LABVIIIa. Greater pollen influx may mean that LABIb received a greater proportion of aerially derived pollen than the other profiles in the early Holocene, perhaps from a wider area, and this argument is reinforced by the high levels of charcoal in LABIb (Fig. 3.40; Section 3.6.2).

Differential pollen influx may also be linked to the distribution of pollen over the lakes sediment surface by water movement, stream inputs and sediment disturbance by wave action or biota.

Edwards and Berridge (1994) and Edwards and Mithen (1995) have suggested that the *Corylus* reduction and increase in Ch:P in LABIb(ii) may reflect human activity. Although there is no archaeological evidence for human occupation this early on Islay, this does not mean that humans were not present on the island. However, the Ch:P curve displays a gradual decline as *Corylus* increases. This suggests that either burning decreased to allow the expansion of woodland or indicates that the charcoal was derived from aerial fallout and screened out by expanding *Corylus* woodland, or was reworked (Edwards, 1990; Edwards and Berridge, 1994).

Inferred climatic oscillations as recorded in stable isotope and pollen data appear to have influenced the early Holocene development of *Corylus* in Fife, eastern Scotland (Whittington *et al.*, 1996; Edwards and Whittington, 1997b; and cf. Walker *et al.*, 1994). The *Corylus* pollen profiles in LABIb(ii) and LABVIIa may also derive from the influence of climatic cooling (Sugden and Edwards, in press) but the impact on the pollen curves may not be as marked at Loch a'Bhogiadh as oceanic influences on the climate of Islay could have ameliorated any reduction in temperatures. The differences between the Loch a'Bhogaidh profiles can also be explained by differences in resolution and the central cores LABI and LABVII may provide an earlier and more regional record of *Corylus* as the slightly earlier date for the hazel expansion on LABVIIa appears to indicate.

3.9.3 LABIc(i) *Betula - Corylus - Isoetes*; LABIIIb(i) *Corylus* - Cyperaceae; LABIVb(i) *Corylus*; LABVb(i) *Corylus*; LABVIb *Corylus*; LABVIIb(i) *Corylus*; LABVIIIb *Corylus* (c. 9400 - 8800 BP [8540 - 7910 cal. BC])

The transition to LABIc(i), LABVIIb(i), LABVIIIb, LABIIIb(i), LABIVb(i), LABVb(i) and LABVIb is marked by a rapid expansion in the *Corylus* curves from c. 10 % up to c. 60 % TLP from c. 9400 BP (8540 cal. BC). This is accompanied by reductions in *Betula,* Poaceae and Cyperaceae pollen and herbs. The earlier expansion of *Corylus* in LABVIII and LABI is discussed above (Section 3.9.2). On LABIII, LABIV and LABVI and LABVIII the *Corylus* expansion appears rapid in percentage terms, and more gradual in LABV and LABVIII and this may be partly explained by different sedimentation rates for the profiles. A more rapid expansion of *Corylus* in the littoral profiles may also be explained by an increased local abundance of this taxon. For the early Holocene c. 9400 BP (8540 cal. BC) *Corylus* pollen influx in marginal profiles LABIII and LABVI is as high as in the central profiles LABVII and LABI.

Human activity has frequently been linked to the expansion of hazel in the early Holocene (Smith, 1970; Simmons and Tooley, 1981; Huntley, 1993), and particularly the rapid increases sustained after its introduction to the pollen profiles. It has been suggested that burning of *Corylus* woodlands may have assisted in propagating young trees and high pollen production may arise from increased flowering. However, high levels of microscopic charcoal in pollen diagrams do not always coincide with the main expansion in *Corylus* (Edwards, 1990), and at Loch a'Bhogaidh Ch:P is low at the *Corylus* rise and actually declines in most of the profiles (LABIIIb(i), LABIVb(i), LABVb(i), LABVIb(i)) compared to previous levels. For the reasons given above (3.9.2), it is unlikely that microscopic charcoal at the *Corylus* rise at Loch a' Bhogaidh was the result of human activity and there is therefore no evidence to link human impact with the main expansion of *Corylus* at the site.

Huntley (1993) has suggested various other reasons for the rapid expansion of *Corylus* in the early Holocene, including climatic influences, soil type and the presence of suitable ecological niches. As the Rhinns of Islay was not reglaciated during the Loch Lomond Readvance (Ballantyne and Dawson, 1997) soils here may have been well developed compared to upland areas of Mull and Skye. With the exception of Beinn Tart a'Mhill there are no extremes of topography in the Loch a'Bhogaidh basin which is sheltered by low lying hills and the area may not have experienced extremes of erosion and associated soil instability. Soils may have been nutrient rich due to local limestone geology (Ballantyne and Dawson, 1997) and hazel can prefer calcareous soils (Moar, 1969). These factors may all have contributed to allow the rapid expansion of *Corylus* at Loch a'Bhogaidh from c. 9400 BP (8540 cal. BC) and the lack of competition from other arboreal taxa (the pollen profiles indicate that only *Betula* was present in any significant amount prior to c. 9400 BP [8540 cal. BC]) would also have allowed *Corylus* to become the predominant arboreal taxon at the site.

3.9.4 LABIc(i) *Betula - Corylus - Isoetes*; LABVIIb(i) *Corylus*; LABb(ii) *Corylus - Isoetes*; LABIIIb(ii) *Corylus*; LABIVb(i) *Corylus*; LABIVb(ii) *Corylus* - Cyperaceae; LABVb(i) Corylus; LABVb(ii) *Corylus -Isoetes*; LABVb(iii) *Corylus*; LABVIb(ii) *Corylus* (c. 8800 - 7700 BP [7910 - 6600 cal. BC])

Following its initial expansion between c. 9700 BP (9300 cal. BC) and c. 9400 BP (8540 cal. BC), *Corylus* becomes the dominant taxon in all profiles (subzones denoted above) reaching percentage values of up to 80 % TLP. Its concentrations average between 50,000 to 100,000 grains cm^{-3} and these do not differ greatly between profiles. The *Corylus* and TLP influx is greater in LABIc(i) and LABVIIb, over 10,000 grains cm^{-2} yr^{-1}, compared with c. 2500 - 5000 grains cm^{-2} yr^{-1} in comparable zones in the peripheral profiles. Nevertheless, in all the subzones, *Corylus* influx is much higher than pollen influx for any other taxa and this confirms the predominance of hazel in the vegetation at Loch a'Bhogiadh from c. 8800 BP (7910 cal. BC).

There are a number of fluctuations occurring in the *Corylus* percentage profiles LABVIIb(i), LABVIIb(ii), LABIIIb(ii), LABIVb(ii), LABVb(i) and b(ii) and LABVIb which are reflected in the concentration and influx data. None of these features are clearly recorded in either LABIc or can be detected in the LABII profile, probably due to the lower sampling intervals at LABI and low sampling intervals combined with a short depth of resolution at LABII.

AMS dating of some of the features on the profiles and the extrapolation of dates on others allows comparison of features between cores, although there are no dates on LABII. Edwards and Berridge (1994) suggested that a reduction in *Corylus* pollen in LABIId(i) occurredc. 7300 BP (6190 cal. BC) corresponding with a similar event dated by extrapolation of dates in LABIc(i). Comparison of these features on both profiles with a later reduction in LABIId(ii) indicates that the initial comparison may not be correct. It is suggested here that the *Corylus* reduction in LABIId(i) is earlier and corresponds with one of the *Corylus* reductions evident between c. 8800 BP (7910 cal. BC) and c. 7700 BP (6600 cal. BC) in the other profiles. The DCA plot of mean subzone scores (Fig. 3.49a) suggests that LABIId(i) corresponds closely with zone b in the new profiles. Edwards and Berridge (1994) also suggested that a transition to peat occurs in the LABIId(i) profile after the clay horizon at about 300 cm, although LOI percentages at this point are lower than would be expected for peat at ~ 40 %. LOI values increase later in the profile (260 cm) to 80 % TLP, which is more representative of peat and evidence in the other profiles indicates that the infilling of peat took place in the southwest of the basin from c. 7000 BP (6010 cal. BC). This would also indicate that the feature in LABIId(i) is earlier than suggested by Edwards and Berridge (1994).

3.9.5 Discussion of the different features in the profiles

The features identified in the pollen profiles and discussed below are indicated on the *Corylus* curves Figures 3.4 - 3.11, 3.20 - 3.37 and on the right hand side of Figures 3.1 - 3.19, 3.38 - 40, 3.43 - 3.48. The depths at which the features occur are provided in Tables 3.4 - 3.6 and noted in the following discussion. Tables 3.4 - 3.6 show the dates allocated to each of the features identified in the profiles and summarize the characteristics of each feature. The overlap in standard deviations for some dates (Fig. 3.50) means that some of the features could refer to the same event on different profiles. However, there are sufficient differences between most of the dates to suggest that these are more likely to represent discrete events.

3.9.5.1 Feature 1a; LABIIIb(i)

A reduction in *Corylus* percentages and increases in Poaceae and Cyperaceae are denoted as Feature 1a (F1a; denoted in Table 3.4 under Feature 1) in LABIIIb(i) c. 9200 BP (8440 cal. BC). A reduction in concentrations corresponds with this feature, and there are slight increases in TD%. The characteristics in Feature 1a are similar to those of the main Feature 1 and both are likely to have resulted from the same influences, hence the interpretation of F1a is given below, with that for Feature 1.

3.9.5.2 Feature 1 (Table 3.4)

AMS dates for similar events both allocated as Feature 1 (F1) in LABVIIb(i) and LABVIb are 9030 ± 65 BP (8190 cal. BC) and 9000 ± 75 BP (8180 cal. BC) respectively. Linear extrapolation of dates on other cores indicates that F1 occurs in the percentage profiles of LABIIIb(ii), LABVb(i) and LABVIb(i). In LABVIIIb c. 9000 BP (8230 cal. BC), a reduction in *Corylus* concentrations only may also represent F1, and a minor reduction in concentrations at this time is also recorded in LABIVb(i).

Although temporary reductions occur in the *Corylus* concentrations in many of the profiles, LABIIIb(i) and LABVIb concentrations display the start of a gradual decline. Simultaneous reductions in total pollen influx of LABVIIIb, LABIVb(i), LABVb(i) and LABVIb also mark the beginning of a progressive decline.

LOI values show a greater degree of variation in the outlying profiles compared to LABIc(i) and LABVIIb. Early in LABVIIIb, LABVIb, and LABIIIb(i), the LOI curves increase whilst in the other relevant profiles LOI is reduced, but not necessarily in conjunction with the *Corylus* percentage reductions. There are no lithological changes noted in the respective zones in any of the cores and no significant increases in Ch:P or TD% are evident. LABVIIIb, LABIIIb(ii) and LABVIb show percentage increases in some taxa including *Ulmus* and *Quercus*, but there is no comparative increase in the concentrations, suggesting that these percentage increases are not a true representation of vegetation dynamics. There are small increases in *Isoetes lacustris* in LABIIIb(i) and LABVb(i) which correlate with fluctuating LOI values, and possibly result from increased nutrient availability due to localised erosion or the inflow of streams.

The bases of zones LABIIIb(i), LABIVb(i), LABVb(i), LABVIb(i), LABVIIb(i) and LABVIIIb (in which F1 occurs) date to c. 9300 BP (8540 cal. BC) where *Corylus* becomes dominant in the pollen profiles. High percentages and concentrations of *Corylus avellana*-type pollen in these zones indicate that this taxon was locally abundant and flowering profusely at this time. Given the indication from the pollen profiles that *Corylus* woodland was well established, the fluctuation LOI values associated with Feature 1 in LABIVb(i), LABVb(i) and LABVIb(i) may have arisen due to the input of eroded materials by streams. LABVI is located close to the slopes at the eastern loch margin from where streams are likely to have drained the higher ground. There are no increases in minor taxa which may represent stream side flora, and no increases in damaged pollen which might indicate the erosion of stream side sediments in Feature 1. However, increases in *Ulmus* pollen in most of the peripheral profiles may result from streams carrying its pollen from the wider catchment area, as *Ulmus* pollen is robust and preserves particularly well. Small increases in *Pinus* pollen in LABVIb(i) may also have been washed down by streams from the better drained slopes above the loch.

Although some reductions in *Corylus* percentages appear in the profiles between c. 9300 BP (8540 cal. BC) and c. 8900 BP (8010 cal. BC), the fluctuating pollen concentration, pollen influx and LOI values for F1 and F1a do not clearly replicate the percentage data, and there are no consistent increases in other taxa which could indicate vegetation succession. This would reinforce the indication that woodland patch dynamics and the influence of stream-borne pollen were responsible for Feature 1 in the profiles. There is no suggestion of human impact at Loch a'Bhogaidh which can be determined from the profiles prior to c. 8900 BP (8010 cal. BC). If people were present in the loch catchment then any impact they may have had on vegetation appears negligible and not reflected in the pollen records. Indeed, small scale human impacts on vegetation could produce similar effects in the percentage pollen profiles to those of early Holocene vegetation dynamics and pollen taphonomic processes as already described, and would thus not be readily differentiated in the pollen profiles.

3.9.5.3 Features 2, 3, 4, 5 and 6 (Table 3.5)

LABVIIb(ii), LABVIIIb, LABIIIb(ii), LABIVb(ii), LABVb(i), LABVIb, LABIId(i)

There are a number of clearly defined features of different dates recorded in profiles LABIVb(ii), LABVb(i) and LABVIb. These are characterised mainly by reductions in *Corylus* pollen percentages and are denoted as Feature 2 (LABIVb(ii)), Feature 3(LABVb(i)), Feature 4 (LABVIb) and Feature 5 (LABIVb(ii)). None of these are represented in LABIc, due to the lower sampling resolution and probably due to what appear to be very local impacts represented by each feature. A small *Corylus* reduction late in LABIIIb(i) c. 8500 BP (7540 cal. BC) could be the same event as Feature 2 on LABIVb(ii), and reductions in *Corylus* c. 8500 BP (7540 cal. BC) and 8000 BP (6910 cal. BC) in LABVIIb(ii) could be representations of the events causing Feature 2, LABIVb(ii) and Feature 5, LABIVb(ii) respectively. However, on LABIIIb(i) and LABVIIb(ii) the reductions are slight and are not clearly presented in concentration curves which display many fluctuations. A reduction in *Corylus* also occurs in LABIId(i), but this remains undated and is referred to as Feature 6.

The dates for features in LABIVb(ii), LABVb(i) and LABVIb have potential overlap when standard deviations are considered (Figure 3.26). However, the summary data (Table 3.4) present no clear matches between features and despite the overlap in standard deviations, these features are as likely to represent different events as the same episode. The features are therefore treated separately. If the date of 8215±80 BP (7290 cal. BC) for the transition of LABIIIb(ii) to the transition to LABIIIc is correct, then the reduction of *Corylus* pollen within LABIIIc may correspond with Feature 4 (LABVb(ii)). However, the pollen assemblage in LABIIIc suggests that this is in fact a later event corresponding with zone c in the other profiles, and that Features 2 - 6 do not present themselves in the LABIIIb(ii) pollen curves. Therefore the *Corylus* reduction in LABIIIc is discussed below as a later event (Section 3.9.5.4).

Feature 2 in LABIVb(ii), 8545 ± 70 BP (7600 cal. BC), shows a reduction in *Corylus* percentages and concentrations, and pollen influx also reduces at the start of an overall decline. LOI falls from 20 % - 10 % and there are increases in Cyperaceae and *Isoetes lacustris*. Estimates of sediment depostion and pollen influx rates suggest that the complete reduction and recovery of *Corylus* lasted c. 120 radiocarbon years.

Feature 3 in LABVb(i), 8270 ± 60 BP (7300 cal. BC) may be characteristic of a greater degree of disturbance in the loch catchment than Feature 2 or may have been closer to the loch. There are again reductions in the *Corylus* percentage and concentration curves, a decrease in pollen influx rates and a decrease in LOI from 60 % - 40 %. The lithology of dark brown gyttja is interrupted by yellow silty gyttja between 400 cm and 403 cm and marked increases in TD% occur. Concentrations of *Isoetes lacustris* increase substantially from 50,000 grains cm^{-3} to 2,000,000 grains cm^{-3} and other taxa including Poaceae, Cyperaceae and *Filipendula* increase. According to sedimentation rates the duration of this episode may be calculated as c. 100 radiocarbon years.

Feature 4 in LABVIb dates to 8155 ± 70 BP (7160 cal. BC). This feature also shows the characteristic *Corylus* reductions of the previous features, plus increases in Cyperaceae and a reduction in LOI from 30 - 18 %. Sediment deposition appears to increase slightly with this feature, probably due to erosion of the slopes to the east of LABVI associated with decreases in woodland there. Sediment deposition rates and pollen influx suggest that this phase of reduction may have lasted c. 120 radiocarbon years.

Feature 5 in LABIVb(ii) occurs from 8000 ± 70 BP (6880 cal. BC). *Corylus* percentages and concentrations and TLP influx are reduced as Cyperaceae and *Filipendula* increase. A rise in LOI from 30 % - 60 % may be explained by slower sediment accumulation rates, although it is also possible that additional organic material was also introduced to the loch by erosion. The length of this *Corylus* reduction is c. 800 radiocarbon years.

Feature 6 in LABIId(i) is defined by a reduction in *Corylus* percentages and concentrations and remains undated. However, dates for the *Corylus* expansion early in LABIId(i) and the later *Corylus* reduction in LABIId(ii) may be estimated by comparison with the other profiles as c. 9200 BP (8440 BC) and c.

7700 BP (6600 BC) respectively. Assuming a uniform rate of sedimentation for LABIId(i), Feaure 6 has an estimated date of c. 8450 BP (7470 cal. BC) and may therefore be the same event as Feature 2 in LABIVb(ii) or Feature 3 in LABVb(i). In addition to a reduction in *Corylus* in LABIId(i), a reduction in LOI values and change from gyttja to clay stratigraphy is recorded. *Isoetes lacustris* increases sharply to c. 800 % TLP and increases in percentages of *Pinus*, *Quercus* and Cyperaceae are also characteristics of this feature.

Compared to the earlier profile zones, the combined LOI and pollen percentage, concentration and influx data suggest less erosion and disturbance to vegetation in the catchment, and more stable sediment accumulation rates, despite occasional disturbances (Features 2-6). The small reductions in *Corylus* percentages and occasional increases in Poaceae, Cyperaceae and herbs may be due to the dynamics of lochside vegetation where temporary clearances may occur due to windthrow of trees, aging or disease. Fossitt (1996) estimates that storm events may produce clearings in woodland which may take 100 - 200 years to recover.

However, the *Corylus* reduction in Feature 5 (LABIVb(ii)) is much longer than the other disturbances at c. 800 years compared with c. 100 years, and is probably reflected in the central profile LABVIIb(ii) as a result of its duration. Feature 3 in LABVb(i) and Feature 4 in LABVIb are of slightly earlier date but the overlaps between dates at the 2 standard deviation level suggest a continued period of interruption in the *Corylus* woodland. The change in stratigraphy coinciding with Feature 3 in LABVb(i) indicates proximity to the loch edge or a period of intense impact on vegetation, and may appear in LABIId(i) as feature 6.

Although climatic changes could be responsible for the recorded reduction in *Corylus*, there is no major event currently recorded which would coincide with this at c. 8000 BP (6910 cal. BC). Neither is there any direct evidence for human occupation on Islay between c. 8500 BP (7540 cal. BC) and c. 8000 BP (6910 cal. BC), AMS dates from Bolsay Farm and Gleann Mor confirm a Mesolithic presence in the area of Loch a'Bhogaidh from c. 7500 BP (6330 cal. BC) (Mithen, pers. comm.). Stone tool assemblages from Islay and Jura could date to the earlier Mesolithic (Mercer, 1970, 1978-80; Mithen and Lake, 1996) and the Mesolithic occupation of Rum is confirmed from 8590±45 BP (7640 cal. BC) (Wickham-Jones, 1990). Pollen evidence from Arran (Robinson and Dickson, 1988) also indicates possible human impacts on *Corylus* woodlands c. 8500 BP (7540 cal. BC). This circumstantial evidence raises the possibility that human activity at the loch edge could have been responsible for at least some of the disturbances denoted by Features 2 - 6, and especially features 3 - 5 which are of long duration, may overlap in time and include the greatest number of disturbance indicators. *Corylus* woodland may have been cleared for use as fuel or other domestic purposes, and hazelnuts gathered for consumption. The absence of an increase in Ch:P in any of the profiles between c. 8500 BP (7540 cal. BC) and c. 8000 BP (6910 cal. BC) indicates that burning was not used as a mode of clearance, if these features are anthropogenic in origin, as has been assumed in the past (Smith, 1977; Simmons and Tooley, 1981). Although some charcoal may derive from domestic fires (Edwards, 1990) the low levels of charcoal associated with the above feature may not have been of local derivation and probably represent a background of aerial fallout or stream-borne component from the wider catchment area. Although Features 3 - 6 may be indications of the clearance of *Corylus* woods by Mesolithic people and could be a precurser to a substantial phase of anthropogenic woodland reduction at Loch a'Bhogaidh, (Section 3.6.2.5), in the absence of any firm evidence of human impact, an interpretation of natural causes must have at least equal validity and the windthrow of trees and grazing and trampling by animals could also have had similar effects.

3.9.5.4 Feature 7 LABIVc, LABVIc and d, LABVIIc and d, LABIc(i), LABVIIIc and d, LABIId(ii), LABIIIc and d, LABVc and d (Tables 3.6 and 3.7)

It was noted by Edwards and Berridge (1994) that reductions in *Corylus* pollen and LOI and small increases in *Betula, Pinus* and herbs occurred in LABIc(i) and a *Corylus* reduction in LABIId(ii) (Figs. 3.4 and 3.5). Increases in *Isoetes lacustris*, which may indicate erosion, appear in LABIc(i) and LABIId(ii), and Ch:P increases, corresponding with the *Corylus* reduction, are evident in LABIId(ii) (Fig. 3.13).

Both Bolsay Farm and Gleann Mor excavations provided evidence of human occupation in proximity to Loch a' Bhogaidh during the Mesolithic. Mithen and Lake (1996) suggest that the lithological evidence from Bolsay represents a lengthy period of human occupation or at least frequent occupations over a long period of time. An AMS date on carbonized hazelnut shell from a context at Bolsay of 7400±55 BP (6300 cal. BC) was obtained (Mithen, pers. comm.). This confirms the presence of people at Loch a'Bhogaidh within the temporal range of the *Corylus* reductions discussed below. Indeed, Edwards and Berridge (1994) postulate that the fluctuating *Corylus* values in LABIc(i) and LABIId(ii) (denoted as Feature 7) could have resulted from human activity at the site.

The reduction in *Corylus* pollen and increases in herbs and charcoal may also have arisen due to a change to a cooler, drier conditions from c. 7700 BP (6600 cal. BC) until c. 7100 BP (5930 cal. BC) (Alley *et al.*, 1997; Barber *et al.*, 1999; Willemse and Törnqvist, 1999). The increases in microscopic charcoal in LABIId(ii) may reflect increases in natural fires in a dry climate.

The additional profiles may assist in interpreting the cause of the disturbances originally detected in LABIc(i) and LABIId(ii) and detail of Feature 7 is provided in Figures 3.58 and 3.59 and Tables 3.6 and 3.7. In Feature 7, increases in *Betula,* Poaceae and herbs are evident in all the profiles, and increases in *Pinus* also occur in all profiles except LABIc(i). There are however, spatial and temporal variations within Feature 7 in the profiles, particularly in LOI, *Isoetes lacustris* and Ch:P, and differences in stratigraphy (summarised in Tables 3.6 and 3.7; Fig. 3.58). Although some of the temporal differences may relate to imprecisions in radiocarbon dates and the inability to precisely correlate sampled levels between the profiles, there nevertheless appears to be a shift in the location of *Corylus* reduction and receipt of Ch:P at Loch a Bhogaidh from c. 7300 BP (6190 cal. BC).

The initial *Corylus* reduction occurs c. 7700 BP (6600 cal. BC) until c. 7300 BP (6190 cal. BC) in profundal profiles LABIc(i), LABVIIc, LABVIc and probably in LABVIIIc. (Although dates on this profile are estimated, the DCA plot Figure 3.49b reinforces this correspondance). Whilst LABIIIc suggests earlier dates for the *Corylus* reduction, it is probable that these are too old, and Feature 7 in LABIIIc may also date from 7700 BP (6600 cal. BC). In the other peripheral profiles LABIVc also indicates a reduction in *Corylus* from c. 7700 BP (6600 cal. BC) but the reduction in LABVc(i) and c(ii) is very slight in percentage terms and does not occur in absolute terms (cf. Figs. 3.8, 3.21, 3.32).

LOI is reduced in LABIc(i), LABVIIc, LABVIIIc, LABIVc and LABVIc whilst LOI values in LABIIIc and LABVc(i) and c(ii) are relatively stable (Figs. 3.12 - 3.19). A reduction in woodland cover would result in greater erosion on slopes to the east of the site compared to the flatter northerly and westerly flanks of the loch (cf. Fig. 3.1b) and this could explain the differences in LOI between the profiles. Indeed, LABIVc has the lowest LOI values of c. 5% and its stratigraphy changes from gyttja to grey silty clay. LOI percentages appear to reduce slightly later in LABVIIc than in the peripheral profiles, and the timing of LOI reductions in LABIc(i) and LABVIIIc may be similar to that in LABVIIc. The comparatively later reduction in LOI in the central profiles could be linked to the time taken to redistribute sediment originally deposited at the loch edges, and the subdued effects of loch edge erosion in the central profiles. Increases in TD% in most of the zones (Tables 3.6 and 3.7; Figs. 3.12 - 3.19) may also be representative of erosion; reworked, older pollen may have been subjected to a greater degree of oxidation and fungal attack than younger pollen, and thus show greater signs of pitting. LABVIc shows the greatest increases in TD% between c. 7700 BP (6600 cal. BC) and 7300 BP (6190 cal. BC).

Ch:P and charcoal influx increases are only present in LABVIIc (Fig. 3.18), LABIIIc (fig. 3.14) and LABVIc (Fig. 3.17) c. 7700 - 7300 BP (6600 - 6190 BC). LABVIc may incorporate re-worked charcoal due to its receiving large amounts of eroded material, and this may have been redistributed to LABVIIc. LABIIIc may also have received redistributed charcoal through wave action and sediment movement but it as likely that the profile received a component of stream-borne pollen and particulates derived from the wider catchment area. This might explain why LABIIIc shows a greater reduction in LOI and a greater increase in charcoal compared to LABVc(i) and c(ii) despite both cores being situated away from the eastern slopes and obvious sources of erosion.

From c. 7300 BP (6190 cal. BC) *Corylus* percentage and absolute reductions intensify in LABIVc and occur in LABVd (refer to Figs. 3.7, 3.8, 3.36, 3.58). It is suggested that the *Corylus* reduction in LABIId(ii) probably originated at a similar time. In LABIVc (Fig. 3.15) and LABIId(ii) (Fig. 3.13), LOI percentages reduce and the stratigraphy of LABIVc changes from gytjja to grey silty clay. The LABVd stratigraphy changes to peat and LOI increases to c. 80 % (Fig. 3.16). Microscopic charcoal increases are particularly evident in LABIVd, LABVd and LABIId(i) (Fig.s 3.15, 3.16, 3.13).

In the other profiles (LABIIId(i), LABVId, LABIc(i), LABVIId(i) and LABVIIId) (Figs. 3.36, 3.58) *Corylus* and LOI recover, although in LABVIId(i) and LABIIId(i) *Corylus* and LOI fluctuate, as do the microscopic charcoal curves. These fluctuations can be explained by the sporadic redistribution of sediment across the loch by wave action, and by streams incorporating pollen from the wider catchment where *Corylus* woodland has recovered.

The additional data from multiple profiles enables a firmer interpretation of Feature 7 than previously provided by LABI and LABII. It is probable that colder climatic conditions from c. 7700 BP (6600 cal. BC) (Alley *et al.*, 1997; Barber *et al.*, 1999; Willemse and Törnqvist, 1999) resulted in a reduction in woodland taxa including *Corylus*, by increasing susceptibility to disease, reducing flowering and therefore propagation, or by direct losses associated with cold and exposure. Trees on exposed slopes where erosion is more likely to occur would have been more susceptible the effects of climate. Most of the profiles show increases in *Betula,* Poaceae, Cyperaceae and tall-herbs at the *Corylus* decline, representing wider areas of birch scrub in the vicinity of Loch a'Bhogaidh. Slight increases in other arboreal taxa may derive from re-worked material due to increased erosion, or wind- and stream-borne pollen transported from a wider area in a more open landscape. Similar mechanisms could be responsible for the increases in microscopic charcoal seen in some of the profiles. An increased frequency of natural fires in a dry open environment could also have contributed to charcoal increases.

Nevertheless, the archaeological evidence confirms a human presence at Loch a'Bhogaidh which coincides with a phase of climatic deterioration. In cold, dry conditions the removal of woodland by people would have compounded the effects of a harsh climate. It may also be considered that earlier disturbances in woodland at Loch a'Bhogaidh recorded c. 8000 BP (Feature 5) may have resulted from human activity but,in a warmer, wetter climate, the effects of this activity would not have had such a great impact. If human activity was at least partially responsible for Feature 7 from c. 7700 - 7300 BP (6600 - 6100 cal. BC), it is unlikely that fire was used to clear woodland close to Loch a'Bhogaidh in view of the low values of Ch:P and low charcoal influx in the peripheral profiles. If the increases in charcoal are not a reflection of natural fires or the re-working of older deposits, then these may derive from the fallout of domestic fires concentrated to the north and east of the loch (cf Edwards, 1990; Edwards and Berridge, 1994) or may derive from the burning of vegetation at a distance from the site.

Evidence from the GISP ice core suggests that a gradual climatic warming began from c. 7300 BP (6190 cal. BC) (Alley *et al.*, 1997) which could explain the recovery in *Corylus* woodland from this time in the wider Loch a'Bhogaidh catchment as indicated by LABIIId(i), LABVIId(i) and LABVId. The continued reduction in *Corylus* to the south and west of the loch as indicated by LABIVc, LABVd and possibly LABIId(ii) may not therefore be explained by the direct effects of climate. The change to peat in LABVd c. 7100 BP (5930 cal. BC) may have resulted from climatic changes and the flatter areas surrounding the loch may have become too waterlogged to support *Corylus*. However, the earlier phase of *Corylus* reduction also appears to have been concentrated to the north-west of the site, and the *Corylus* curve is relatively unchanged in LABVc between c. 7700-7300 BP (6600 - 6190 cal. BC) when woodland reduction would have encouraged peat formation. The increases in microscopic charcoal (both Ch:P and influx; Figs. 3.15 and 3.16) associated with the latter *Corylus* reduction in LABIVc and LABVd from c. 7300 BP (6190 cal. BC) suggest that people may have cleared woodland at the loch edges and this may have encouraged the growth of peat.

The data provided by multiple profiles at Loch a'Bhogaidh therefore suggest that, although a period of cooling in the Atlantic may have reduced woodland in the loch catchment, and produced episodes of erosion from c. 7700 BP (6600 cal. BC) people may also have cleared areas of vegetation at Loch a'Bhogaidh and may have been responsible for enhancing the effects of climatic changes from c. 7700 BP (6600 cal. BC).

3.10 Infilling of the loch with peat

If the complete stratigraphies of each profile are considered (Fig. 3.61), then the development of peat occurs in some the peripheral profiles (excluding LABVI) shortly after the inferred episode of woodland clearance discussed above, c. 7000 BP (5870 cal. BC). Peat appears in the stratigraphy LABVd at 360 cm at c. 7100 BP (5930 cal. BC) and in LABIIe at 255 cm c. 7000 BP (5870 cal. BC), with associated increases in LOI, Cyperaceae and in LABIIe increases in Ranunculaceae and *Equisetum.*Peat occurs in the LABIII profile c. 6500 bP (5460 cal. BC) although this might be later, given the possibly erroneous dates on this profile, or earlier. The latter is perhaps more likely given the subdued topography in the west of the Loch a'Bhogaidh catchment, as this area would be more prone to waterlogging. A change in hydrological conditions could have limited the subsequent regeneration of *Corylus* woodland to the north of the loch and the *Corylus* recovery in LABIIId probably incorporates'*Corylus* pollen from further afield.

Peat development occurs c. 4000 BP (2530 cal. BC) in LABI and LABVII and c. 5000 BP (3860 cal. BC) in LABVIII. Given the potential inaccuracies in extrapolated radiocarbon dates, peat inception for these profiles appears to have occurred around the same time. The relatively late development of peat in LABIV (ca. 3000 BP [1200 cal. BC]) and LABVI (ca. 1000 BP [1060 cal. AD]) was probably influenced by the position of these sites close to slopes at the east of the loch. These slopes appear to have remained wooded later than elsewhere, given the relatively higher percentages of *Corylus* in LABVId and LABIVd until c. 6500 BP (5460 cal. BC).

It is therefore possible that the activities of Mesolithic people at Loch a'Bhogaidh may have influenced the expansion of peat in the area. Mesolithic impacts elsewhere have been linked to peat development (Caseldine and Hatton, 1993; Simmons and Tooley, 1981) and at the Bolsay site near Loch a'Bhogaidh, podzolisation followed by peat development is evident in post-occupation horizons. Climatic changes mentioned earlier may also have assisted in peat development by reducing *Corylus* woodland at Loch a'Bhogaidh. It is unlikely, however, that sufficient waterlogging for peat formation could have occurred c. 7700 - 7300 BP (6600 - 5910 cal. BC) which was particularly cold and dry (Alley *et al.*, 1997). From c. 7300 BP (5910 cal. BC) climatic conditions became gradually warmer and wetter, and the reduction in *Corylus* to the southwest of the loch from this time may have encourage peat growth, although woodland reduction may also have occurred due to human activity compounding the time-lag effects of earlier climatic events.

3.11 Conclusions

The pollen profiles from Loch a'Bhogaidh reinforce the original interpretations of LABI and LABII (Edwards and Berridge, 1994) with regard to the succession of Holocene taxa. However, different features occur in separate profiles, and these variations enhance interpretation.

The multiple representations of the *Corylus* rise at Loch a'Bhogaidh suggest that centrally placed profiles may receive greater amounts of airborne pollen from a wide area, but other central profiles do not show changes.

The variations in influx between the profiles through time also indicate that sediment focusing and pollen distribution may not be constant over the catchment.

Additional detail of vegetation history was created by the use of multiple profiles, and between c. 8500 BP (7540 cal. BC) and c. 8000 BP (6910 cal. BC), a number of fluctuations occur in the various profiles at different times, although there is no evidence to directly confirm the cause of these. Openings in woodland may result from natural environmental changes but it is also possible that at least some of these represent Mesolithic activity. In contrast, what appeared to be a small scale reduction in *Corylus* in LABIc(i) is provided in much greater detail in the multiple profiles as a climatic event with possible human impact superimposed. This detail and the array of AMS dates on the profiles enhances an interpretation of climatic change and human interference altering catchment vegetation, and raises the possibility that temporal changes in the concentration and location of human activity may be detected at other sites.

The Loch a'Bhogaidh profiles tend to confirm the hypothesis that deep, centrally placed profiles may not detect small scale impacts at a loch edge, and where considerable vegetation changes are evident, their representations in central cores may be muted and lack detail. The results from Loch a'Bhogaidh present a strong case for the employment of multiple profiles in pollen studies provided these are combined with rigorous AMS dating and close resolution sampling.

CHAPTER 4 - POLLEN ANALYSIS OF SEDIMENTS FROM LOCH AN T'SUIDHE, ROSS OF MULL

4.1 Site description

Loch an t'Suidhe (Figure 4.1; Plate 4.1), NGR NM 371 215, is located on the Ross of Mull in the south west of the island and directly south of the Isle of Ulva. Approximately 50m in diameter, it lies less than 500 m from the northern coastline of the Ross of Mull in an area of flat bog surrounded by low hills (maximum 85 m O.D.). The hills support a sparse vegetation of Poaceae spp., Cyperaceae spp. and *Calluna vulgaris.* The surrounding bog is dominated by *Myrica gale* and other vegetation includes *Sphagnum* spp., *Eriophorum angustifolium, E. vaginatum, Erica tetralix*, *Juncus* spp., *Potentilla erecta* and *P. palustris.* The open water of the loch supports *Nymphaea alba* and the fringing hydrosere is dominated by *Sphagnum* spp. The extent of open water in the past at Loch an t'Suidhe is unknown, and the surrounding mire probably represents an area of infilling.

Currently there are no streams flowing into the loch, but it may have been stream-fed in the past. If this was the case, then stream input may not have been large due to the subdued topography surrounding the loch and the flat valley floor in which it is situated (See Plate 4.1).

A pollen surface sample (Fig. 4.2) from the southern edge of Loch an t'Suidhe show the predominance of *Myrica gale* in the surrounding mire. The Bunessan area on the Ross of Mull is virtually treeless, and the lack of arboreal pollen in the surface samples indicates that most of the *Corylus avellana*-type pollen in the assemblage is probably *Myrica*, despite the low pollen productivity of this taxon (Birks and Huntley, 1983).

4.2 Background to the present study

Lowe and Walker (1986a, 1986b) carried out pollen analysis on a core from the southern edge Loch an t'Suidhe. Their pollen sampling intervals were between 8 and 10 cm with TLP counts of about 300 TLP, and there was no quantification of microscopic charcoal. Their profile, LS, is undated, and a proposed chronology was constructed by comparison with other pollen profiles from Mull. Only the percentage data were published. For the present study, a further core (2LS) was obtained from the southern edge of Loch an t'Suidhe. Pollen samples were extracted at intervals of 2 - 4 cm and TLP counts of at least 500 were achieved. Microscopic charcoal quantification and damaged pollen analyses were also undertaken and 6 AMS dates (Table 4.1) allow the estimation of sediment deposition times and pollen influx rates.

The lithologies of LS and 2LS are similar, consisting of dark brown to black gyttja of Holocene date, which overlays a series of grey and green clays, of Lateglacial origin.

As this research aims to detect human impacts in the early Holocene pollen record, samples for pollen were extracted from the Holocene gyttja sediment until a decline in *Ulmus* pollen and increase in Poaceae pollen were detected. These were evident in the Lowe and Walker (1986b) profile and with an estimated date of c. 5000 BP (3860 cal. BC), the *Ulmus* decline may be used as a marker to ensure the capture of the vegetation history of the Mesolithic period.

4.3 Pollen diagrams and zones

The relevant portion of the published LS pollen diagram is provided in Figures 4.3a and b. The percentage, concentration, pollen influx, damaged pollen and summary data profiles for 2LS are provided in Figs. 4.4 - 4.8. An age-depth curve for the Loch an t'Suidhe profile showing 2SD error bars is presented in Figure 4.9 and details of radiocarbon dates are presented in Table 4.1. The zones allocated to 2LS correspond closely to those from Lowe and Walker's (1986b) and comparisons of appropriate zones and allocated dates are summarised in Table 4.2.

4.4 Discussion of zones

4.4.1 2LSa c. 9800 - 7900 BP (8910 - 6810 cal. BC)

Subzone 2LSa(i) *Betula* - Cyperaceae - *Filipendula* c. 9800 - 9200 BP (8910 - 8500 cal. BC)

The base of the profile in 2LSa(i) dates from 9870±75 BP (8910 cal. BC) and the subzone incorporates high percentage values of *Betula*, Poaceae, Cyperaceae and *Filipendula* in addition to the aquatic taxa *Myriophyllum alterniflorum* and *Littorella uniflora. Corylus avellana*-type pollen is present in low amounts and although Ch:P values are high, c. 100 x 10^{-8}, low charcoal influx compares with low TLP influx values. These are probably a product of rapid sedimentation rates which average 125 cm yr^{-1} in 2LSa. LOI rises from 20 % and continues to rise through the transition to 2LSa(ii).

A DCA plot of mean subzone scores (Fig. 4.10) suggests that 2LSa(i) is very different to the other profile zones and if more than two sampled levels had been available then 2LSa(i) would have been classified as a zone in its own right. The arboreal pollen is limited to *Betula*; low influx for this taxon implies that *Betula* was scarce in the early Holocene and damp grassland with tall-herbs appears to have been the predominant vegetation. Steadily increasing LOI values reflect soil development and the presence of *Myriophyllum alterniflorum* indicates the amelioration of climate from earlier Lateglacial conditions. The microscopic charcoal in 2LSa(i) may derive from reworked charcoal deposited through erosion, or from aerial fallout in a relatively open environment. The reductions of Ch:P at the transition to 2LSa(ii) probably result from the screening out of charcoal particulates by expanding woodland. A reduction in charcoal influx is also discernible, despite very low values. There is therefore no suggestion at Loch an t'Suidhe of any burning at the *Corylus* rise which may be linked to its expansion and possible human interference (cf. Smith, 1977; Edwards, 1990).

The date for the *Corylus* rise is estimated by linear extrapolation as c. 9250 BP (8500 cal. BC). This is slightly later than the date for the *Corylus* rise at Loch a'Bhogaidh c. 9400 BP (8650 cal. BC) (Chapter 3) and on Arran, c. 9400 BP, (8650 cal. BC)_(Robinson and Dickson, 1988), but is earlier than recorded elsewhere on Mull (Walker and Lowe, 1985, 1987; Lowe and Walker, 1986a, 1986b), and Skye (Birks, 1977; Walker and Lowe, 1990; 1991). Local environmental factors are probably responsible for the varying times of the *Corylus* expansions in the Inner Hebrides and these are discussed in Chapter 7.

LSa(ii) *Betula - Corylus*. c. 9200 - 7900 BP (8500 - 6810 cal. BC)

Within 2LSa(ii) *Betula* and *Corylus* are the dominant taxa and *Salix* is also present, but decreases in the latter part of the subzone. *Ulmus* and *Quercus* expand c. 8700 BP and 8200 BP (7790 and 7280 cal. BC) respectively. These dates compare well with those from other Inner Hebridean sites (Birks and Huntley, 1983; Birks, 1989; refer to Chapter 7). Poaceae and Cyperaceae persist in low amounts, and occasional herbs < 2 % TLP are recorded, including *Potentilla, Rumex acetosa* and *Succisa pratensis*. *Equisetum* and ferns (Pteropsida (monolete) indet.) are also present. The low arboreal pollen influx values (including *Betula* and *Corylus*) in 2LSa(ii) suggest that woodland near the site remained scarce until c. 8000 BP (6860 cal. BC) although rapid sediment accumulation rates will also have influenced pollen influx values. Poaceae gradually reduce in percentage and absolute values within 2LSa(ii), probably as a response to the expansion of woodland, but the damp grassland communities recorded earlier in 2LSa(i) persist throughout this zone as is evident from the assemblage of herbs, *Equisetum* and ferns.

From c. 8000 BP (6860 cal. BC) there is a reduction in LOI from 50 % to 25 %, which indicates the introduction of minerogenic material to the loch and values remain low (~ 25 %) within the subsequent subzone, 2LSb(i). There are no reductions in the pollen profiles which could be associated with this although a contemporary increase in pollen influx values at c. 8000 BP (6860 cal. BC) suggests a deceleration of sedimentation which could have changed organic accumulations and influenced LOI.

4.4.2 2LSb c. 7900 - 6850 BP (6810 - 5870 cal. BC)

2LSb(i) c. 7900 - 7000 BP (6810 - 5870 cal. BC) Poaceae - Cyperaceae - *Calluna*.

At the base of 2LSb(i), *Betula* and *Corylus* pollen are predominant, but *Pinus sylvestris, Ulmus* and *Quercus* are well represented, and the assemblage suggests that a mixed deciduous woodland inhabited the Loch an t'Suidhe catchment at 7875±60 BP (6720 cal. BC) and pine may have been locally present. Shortly after this time reductions in *Betula* and *Corylus* percentages, concentrations and pollen influx values occur, and these correspond with increases in Poaceae, Cyperaceae, *Calluna vulgaris* and

Sphagnum. The pollen of various herbs is also recorded within this subzone, and include *Potentilla, Rumex acetosa* and Chenopodiaceae. A DCA plot of taxon scores for 2LSb (Fig. 4.12) is notdissimilarto one for taxa from the whole profile (Fig. 4.13) although axes one and two are reversed. This might indicate the general uniformity of the 2LS profile (dominated by arboreal pollen). Nevertheless, *Calluna vulgaris* and *Filipendula* are more closely associated with Poaceae and Cyperaceae in Figure 4.12 which reflects the decrease in arboreal pollen and increase in herbs in 2LSb.

The pollen data therefore indicate that local *Betula-Corylus* woodland at Loch an t'Suidhe declined, and was replaced by a herb rich grassland. The increases in *Sphagnum* may represent local waterlogging resulting from a decline in woodland cover. This is dated to between 7700 and 7100 BP (cal. 8440 and 7890 BP) and coincides with a period of climatic cooling detected in the GISP2 ice core record from central Greenland (Alley *et al.*, 1997), marine sediment and ^{14}C records from the Hudson Bay area, eastern Canada (Barber *et al.*, 1999) and lake sediments from Greenland (Willemse and Törnqvist, 1999). The reduction in arboreal pollen is also similar to Feature 7 identified in the Loch a'Bhogaidh profiles (Chapter 3). 2LSb(i) is therefore likely to represent colder, drier conditions which occurred in the early Holocene.

However, it is *Betula* and *Corylus* which experience the greatest reductions in both percentage and absolute terms. Other arboreal taxa sustain their values, and even if these represent the background noise of long distance pollen transport, a reduction in other arboreal taxa, particularly *Quercus* and *Ulmus,* could be expected in a period of sustained cooling, particularly one so severe as to affect *Betula,* a pioneering taxon capable of surviving relatively poor climatic conditions.

LOI values at the transition to 2LSb(i) appear stable c. 28 %, and although LOI continues to increase through the mid to latter part of the zone, the curve is punctuated by several extreme reductions in LOI, suggesting the periodic inwash of mineral matter into the loch, although no minerogenic layers or stratigraphic changes were apparent. Erosion would be expected if woodland cover in the local area was reduced. Ch:P increases substantially in 2LSb(i) and charcoal influx increases to from c. 50 cm^{-2} cm^{-3} yr^{-1} to c. 300 cm^{-2} cm^{-3} yr^{-1} and reaches a maximum of 1340 cm^{-2} cm^{-3} yr^{-1}. These increases in the charcoal records may have arisen from a reduction of the woodland screen surrounding the site due to the effects of an increasingly cold climate. In 2LSb(i) however, charcoal influx is much greater than in 2LSa, where the environment appears to have been less wooded and where a greater proportion of charcoal was probably of aerial derivation. The reduction of woodland in 2LSb(i) could have created a greater amount of mineral inwash to the loch, and thus introduced reworked charcoal, but again, LOI was lower in the earlier zone where Ch:P and charcoal influx were lower. If the charcoal increase recorded in this subzone had resulted from washed-in charcoal then it would appear to be contemporary with the pollen, and is likely to represent local burning. Indeed, the appearances of *Calluna vulgaris, Potentilla* (possibly *erecta*) and *Pteridium aquilinum* reinforce the case for local burning, as these may all be favoured by fire (Page 1976, Hobbs and Gimingham,1988; Edwards *et al.*, 1995).

Although a drier, colder climate could have increased the potential for natural fires between c. 7700 and 7100 BP (cal. 8440 and 7890 BP) (Edwards *et al*, in press) the woodland reduction at Loch an t'Suidhe between c. 7800 and c. 6900 BP (6900 and 5780 cal. BC) in 2LSb(i) may reflect Mesolithic cultural activity. The potential anthropogenic indicators

Aster-type, *Cirsium*-type, *Artemisia*, Chenopodiaceae and *Rumex acetosa* are all recorded in this subzone although these taxa would also occur naturally in woodland openings and in the disturbed ground resulting from cold, dry climatic regimes. There is currently no evidence for a Mesolithic presence in the south of Mull, but Livingstone's Cave on the nearby island of Ulva was occupied during this period (Bonsall *et al.*, 1991, 1995), a midden of probable Mesolithic date was recently discovered at Dervaig in northern Mull (Robins, 1998) and there is a wealth of evidence for Mesolithic occupation in the other Inner Hebridean islands (Chapter 1, Section 1.2). It seems inconceivable that many other parts of Mull, and especially coastal areas, would not have been visited by human communities at this time. Other pollen profiles from western Scotland display reductions in woodland taxa of similar Mesolithic dates. Human activity may feature in the profiles from Loch a'Bhogaidh, Islay, superimposed on the effects of climatic changes which occurred between c. 7700 - 7000 BP (6600 - 6010 cal. BC) (Chapter 3). A similar phase of inferred human impact also occurs at Loch Cholla, Colonsay between c. 7800 - 6050 cal. BP (Andrews et al., 1987; Edwards, in press) although this may also have been initiated by climatic changes. Two short phases of woodland reduction and increases in *Calluna vulgaris* and charcoal are recorded in the pollen record from Loch an t'Sil, South Uist from c. 8025 BP to c. 7900 BP (6810 - 6770 cal. BC) and from c. 7850 BP to c. 7790 BP (6640 - 6770 cal. BC) (Edwards, 1996; Edwards, 1998). Woodland reductions of possible anthropogenic origin on Rum occur later, c. 6000 - 5750 BP (4560 - 4610 cal. BC) and 5250 - 4950 BP (4100 - 3800 cal. BC). The pollen profiles from Loch an t'Sil in particular correspond closely to those from Loch an t'Suidhe in that reductions in *Betula* and *Corylus*. and increases in *Calluna vulgaris*, Poaceae, *Potentilla* and Ch:P occur (Edwards, 1996, 1998). The shorter reductions in woodland and increases in herbs are perhaps more likely to be the result of human activity, but, when combined with the abundant archaeological evidence for Mesolithic occupation of the Inner Hebrides, that human activity could be incorporated with the effects of climate change in the Loch an t'Suidhe profile. A multiple profile strategy such as that employed at Loch a'Bhogaidh may have assisted in determining the extent of any spatial distribution in vegetation patterns within 2LSb(i) and could therefore have assisted in identifying whether or not the subzone is purely a reflection of climate, or whether human impacts on vegetation also occurred.

If the increases in microscopic charcoal at Loch an t'Suidhe and Loch an t'Sìl are anthropogenic in origin, they may represent the use of fire to create or maintain heath and grassland as grazing for game and fowl (Simmons and Tooley, 1981; cf. Edwards, 1996, 1998). However, woodland may have been cleared by other methods, and fallout from the domestic fires of hunter-gatherers could have increased amounts of fossil charcoal (cf Edwards, 1990; 1996; 1998) although absolute charcoal values and Ch:P at Loch an t'Suidhe appear very high, and might be thought unlikely to derive solely from camp fires. A drier, colder climate may have increased the potential for natural fires, but also the Mesolithic use of fire, whether originating as intentional or accidental.

2LSb(ii) *Betula* - *Corylus* c. 7000 - 6850 BP (5870 - 5770 cal. BC)

In the transition to 2LSb(ii), *Betula* and *Corylus* display a progressive recovery as Poaceae and *Calluna vulgaris* reduce. However, within the subzone, *Betula* percentages, concentrations and influx decline, possibly as the result of an expansion of *Corylus* and *Salix*. Fewer herbs are recorded compared to 2LSb(i) and Poaceae, Cyperaceae and *Calluna vulgaris* are substantially reduced from former values and absolute charcoal values and

Ch:P remain low. This subzone assemblage indicates a recovery in woodland following the cessation of the proposed preceeding human activity.

A fall in LOI from 40 % to 5 % in 2LSb(ii) reflects erosion and the deposition of mineral matter into the loch. There are small increases in TD% within this subzone which reinforce the suggestion of erosion, although the only notable increases in damage for a single taxon occur for *Calluna vulgaris*. These occur as its overall percentages fall, and the values for damage are possibly a function of the low numbers of *Calluna* pollen recorded rather than any change in taphonomy for heather pollen. There are no other indications of erosion from the pollen record and indeed, most of the arboreal pollen curves increase. It is possible that the arboreal pollen is of very local origin whereas actual erosion may have taken place in the wider catchment. The fall in LOI may appear due to increased minerogenic input from streams flowing into the loch. If erosion took place close to the loch, then this was probably small scale, and the comparative abundance of arboreal pollen over non-arboreal pollen may have prevented the pollen indicators of taxa from open and disturbed ground being detected in the pollen record.

Alnus glutinosa reaches its rational limit at Loch an t'Suidhe in 2LSb(ii) c. 6800 BP (5700 cal. BC), a date earlier than predicted by isopollen maps (Birks and Huntley, 1983) and pollen isochrones (Birks, 1989). Although there is no evidence of human activity in the pollen spectra of 2LSb(ii), the possible human impacts recorded earlier in 2LSb(i) could have brought about changes in the Loch an t'Suidhe catchment, and created an ecological niche for the expansion of *Alnus* in the area. Indeed, *Alnus* is consistently present in the earlier subzone 2LSb(i) in low amounts (< 2% TLP) and this may signify that *Alnus* was a minor component of local woodland, or was at least present in the catchment although at some distance from the pollen core site (cf. Bennett, 1983). The earlier reductions in *Betula-Corylus* woodland in 2LSb(i) may have created wetter downslope habitats increases in *Salix* in 2LSb(ii) could also reflect this.

4.4.3 2LSc *Alnus - Corylus - Betula - Quercus* c. 6850 - 5200 BP (5770 - 4100 cal. BC)

In the transition to 2LSc at 6845±55 BP (5720 cal. BC), the *Betula, Pinus, Ulmus* and *Quercus* profiles maintain the percentage and absolute values of the previous subzone, but *Ulmus* and *Quercus* expand later in the zone. Although a temporary decline appears in the *Corylus* percentage curve as *Alnus glutinosa* values rise, *Corylus* influx values are not greatly reduced and the pollen assemblage indicates the local presence of a mixed woodland. Only low values of Poaceae, Cyperaceae and herbs are recorded, and arboreal pollen influx curves are comparatively high, confirming the predominance of woodland in the area.

A reduction in LOI occurs at the base of 2LSc, and a similar reduction occurs later in the zone at 655 cm, indicating two short episodes of minerogenic inwash to the loch. There are no simultaneous decreases in the pollen percentage profiles or increases in damaged pollen which could signify erosion, but reductions in the pollen influx curves c. 6500 BP (5460 cal. BC) and c. 6100 BP (4820 cal. BC) coincide with the reductions in LOI. Although microscopic charcoal is not recorded in notable quantities at every level, comparatively high charcoal influx, concentrations and Ch:P are intermittently recorded compared to 2LSb and in particular at the first reduction in LOI at the base of the zone. Increases in charcoal may derive from episodes of inwash into the loch and periodic increases in sediment accumulation may also have occurred, thus reducing pollen influx.

From c. 6000 BP (4560 cal. BC), LOI values remain around 70 % for the remainder of the zone and charcoal concentrations, influx and Ch:P fall, suggesting less erosion. The LOI values are high for gyttja and could represent the infilling of the loch with peat. Alternatively the high LOI values could suggest a build-up of rich, organic matter and low decomposition rates resulting from the very local presence of damp woodland. The location of core 2LS may not have been far from the loch edge at the south of the basin from c. 6000 BP (4560 cal. BC).

Pinus pollen percentages and absolute values decrease from 7 % TLP to < 2 % TLP in the lower part of 2LSc. This occurs shortly after the decrease in LOI, but *Pinus* percentages are probably too low to reflect a local presence (Bennett, 1984; Willis *et al.*, 1998) and the *Pinus* pollen influx curve is also low compared to those of other arboreal pollen types. This indicates that *Pinus* was not a major component of local woodland and most of its pollen in the profiles probably derives from long distance transport. The reduction of *Pinus* pollen occurs c. 6650 BP (5600 cal. BC) in 2LSc, and this is early compared with reductions at other sites in Scotland where climatic deterioration is probably responsible (Bennett, 1984; Gear and Huntley, 1991; Willis *et al.*, 1998). *Pinus* influx values throughout the zone are not much lower than previously recorded, and the apparent reduction of *Pinus* may be an artefact of the percentage diagram in response to increases in *Alnus*, *Ulmus* and *Quercus*. Increased woodland cover could also have screened out *Pinus* pollen from the site, thus mitigating its representation in 2LSc. Woodland cover would also have screened out charcoal particulates and may therefore be partly responsible for the reductions in charcoal influx in the later part of 2LSc. In this zone, the pollen of Poaceae and Cyperaceae is recorded mostly in values of < 2 % TLP, and herbs such as *Filipendula* and *Potentilla* feature sporadically and are also only present in very low amounts, reinforcing the suggestion that woodland became denser at Loch an t'Suidhe from c. 6800 BP (5770 cal. BC).

4.4.4 2LSd *Betula - Alnus - Corylus* - Poaceae c. 5200 - 4550 BP (4010 - 3260 cal. BC)

Within 2LSd, the arboreal pollen percentages and absolute values recorded in the previous zone are maintained for *Betula, Pinus, Quercus* and *Corylus. Alnus glutinosa* expands slightly however, and there is a clear decline in *Ulmus* at c. 5100 BP to < 2 % TLP. *Ulmus* recovers in the later part of the zone, but does not achieve the values recorded earlier in the profile. The Poaceae curve exhibits an expansion towards the end of 2LSd, and herbs are recorded more frequently within this zone, and include *Plantago lanceolata* and *Rumex acetosa*. LOI values are high ~ 75 %, although percentages reduce towards the end of the zone.

The date for the *Ulmus* decline at Loch an t'Suidhe corresponds with the date of c. 5100 BP (3860 cal. BC) attributed to the main British elm decline. A variety of causes have been hypothesised for this event (refer to Chapter 7), including disease, climatic deterioration and increased human activity. It is entirely possible that climatic changes were responsible for the decline in *Ulmus* at Loch an t'Suidhe. The site is in an exposed position on the Ross of Mull peninsula and subjected to salt-laden westerly winds and rain from the Atlantic Ocean. Increases in rainfall could have increased the leaching and acidification of local soils and the expansion of *Alnus* within 2LSd may be a response to increased wetness. *Ulmus* may have inhabited the slopes surrounding Loch an t'Suidhe rather than the wetter valley floor, which will have had a greater susceptibility to erosion and leaching due to increased rainfall. Disease may also have caused the deaths of *Ulmus* specimens and resulted in woodland openings which could also have contributed to increased erosion into the loch.

Although human activity may also have contributed to the *Ulmus* decline in some areas of the British Isles, either directly or by exacerbating the effects of natural environmental changes, there is no strong evidence in 2LSd which could support the theory of a human presence at Loch an t'Suidhe c. 5100 BP (3860 cal. BC). Small increases in Poaceae, *Plantago lanceolata and Rumex acetosa* and a reduction in LOI probably result from the exposure of soils and associated erosion. This could have resulted from the mechanisms described above, but could also have been caused by human activity. Although Ch:P remains low, there are small increases in charcoal concentrations and influx although these are not substantial and charcoal is only recorded intermittently in this zone.

Whilst the loch does not currently receive stream-borned inputs, periods of higher rainfall may have caused streamflow into Loch an t'Suidhe. The weak signal of cultural activity, including the intermittent charcoal record, associated with the *Ulmus* decline in 2LSd may therefore be explained as having arisen from the far edges of the catchment if stream-borne pollen is a component of this zone assemblage.

4.5 Summary of Holocene vegetation history at Loch an t'Suidhe to c. 5000 BP (3860 cal. BC)

The pollen data indicate that *Betula* scrub and grassland comprised the early Holocene flora at Loch an t'Suidhe from c. 9800 BP (8910 cal. BC). *Corylus* expanded shortly after c. 9200 BP (8500 cal. BC) and by c. 8000 BP (6860 cal. BC) *Ulmus* and *Quercus* were introduced to the woodland flora. A decrease in woodland from c. 7750 BP to 6900 BP (6620 - 5780 cal. BC) and expansions in *Calluna vulgaris,* Poaceae and herbs may have been caused by the actions of Mesolithic people. A coincidental increase in Ch:P suggests that burning could have occurred locally, and was probably anthropogenic in origin.

A regeneration of woodland is indicated from c. 6900 BP (5780 cal. BC) and the expansion of *Alnus* shortly after this may be linked to increased wetness within the Loch an t'Suidhe catchment. The reduction of *Pinus* following the *Alnus* expansion may also be linked to increased wetness of the valley floor, and *Alnus* outcompeting *Pinus* at the site, although falls in *Pinus* pollen could equally be explained by the screening out of its pollen by expanding woodland or as an artefact of the percentage data. The earlier reduction of *Betula - Corylus* woodland between c. 7750 to c. 6900 BP (6620 - 5780 cal. BC) could have been influential in hydrological changes at Loch an t'Suidhe and assisted in the spread of *Alnus* there.

From c. 6800 BP (5750 cal. BC) a mixed woodland of *Alnus, Corylus, Quercus, Ulmus* and *Betula* persisted at Loch an t'Suidhe and after this time there is no strong evidence in the profiles for local fires or human impacts. At 5235 ± 55 BP (5100 cal. BC), *Ulmus* pollen values decline as NAP values increase and LOI values reduce. Whilst human activity may have caused this a combination of climatic and local edaphic influences and disease may also have been responsible for this event.

CHAPTER 5 - ULVA. Discussion of multiple profiles from two peat filled basins

5.1 Site descriptions and background to the project

Two peat-filled basins on Ulva to the north and west of Livingstone's Cave were selected for sampling.

A'Chrannag bog (Figure 5.1; Plate 5.1), NGR NM 431 391, is a topographic mire at 74m O.D. located 250 m east of the summit of A'Chrannag on Ulva and 500 m north of the archaeological site of Livingstone's Cave. The dimensions of the bog are approximately 300 m east-west and 200 m north-south and it is bordered by higher, rocky ground which is exposed to southwesterly winds. The bog surface appears to have been cutover in the past. Small pockets of *Betula pubescens* and *Salix* spp. occur around its perimeter which is drier, and *Pteridium aquilinum* is present on the rockier slopes. The surface flora includes *Eriophorum angustifolium* and *E. vaginatum*, *Potentilla erecta*, *Myrica gale, Calluna vulgaris*, *Dactylorhiza maculata* ssp. *ericitorum* and *D. purpurella* amongst other species. In wetter areas *Juncus* spp., *Potamogeton* spp., *Hydrocotyle vulgaris* and *Myosotis scorpioides* are common.

Both east-west and north-south depth transects were measured to provide an indication of sub-peat topography (Figs. 5.1, 5.2) and to assist in locating coring positions. Two cores were taken in the A'Chrannag basin, one from the deepest part of the bog in the north-west (AC1; NGR NM 432 391), and the other from a pocket where peat deepens in the north-south profile at the southern bog edge closest to the cave (AC2; NGR NM 432 389) (Fig. 5.1).

The peat in both profiles overlays a green clay horizon which grades down into sandier deposits.

Livingstone's Cave mire (Fig. 5.1; Plate 5.2), NGR NM 431 386, was formed in a topographic depression to the west of Livingstone's Cave. It is situated to the south of A'Chrannag bog at c. 30 m O.D. and 300 m to the west of Livingstone's Cave. The bog is also 500 m north of the basalt cliffs of Ulva's south coast which are exposed to southwesterly winds from the sea. The basin itself is relatively sheltered as it is bounded by low rocky outcrops to the west and shallow slopes to the east.

The slopes around the bog support *Corylus avellana*, *Betula pubescens* and *Salix* spp. woodland with an understorey of ferns, mosses, and Poaceae. Flowering herbs include *Allium ursinum*, *Oxalis acetosella*, *Primula vulgaris* and *Campanula rotundifolia*. The north of the bog is drier than the south, and vegetation is dominated by *Calluna vulgaris* and *Myrica gale*. As wetness increases to the south the flora becomes more diverse. Species present include *Eriophorum angustifolium*, *Filipendula ulmaria*, *Juncus effusus*, *Potentilla erecta*, *P. palustris* and *Iris pseudacoris*. *Potamogeton* spp. and *Sphagnum* spp. are also present.

The dimensions of the mire are approximately 250 m north-south and 150 m east-west. Depth transects were measured across the bog, one across the north-south dimensions, and three at intervals across this from east to west (Figs. 5.1; 5.3). Two cores were extracted, LC1 to the middle of the bog (NGR NM 431 386), and LC2 to the eastern edge of the bog (NGR NM 432 385) (Fig. 5.1). The peat in both cores overlays sandy green clay under which is a further depth of organic sediments. These also overlay sandy green clays which becomes yellow brown and sandier with depth. Profile stratigraphies are included in the pollen diagrams, (Figs. 5.20 and 5.21).

5.2 Minerogenic sediments

The mineral sediments underlying all the cores, and those intersecting the Livingstone's Cave peat profiles (refer to lithologies on Figs. 5.10, 5.11, 5.20, 5.21) apear to be similar to those from an un-named mire 200 m west of Livingstone's Cave at 20 m O.D. and described by Bonsall *et al.,* (1991: 9-10) as

> " marine sands grading upwards into shallow lagoonal facies brackish marine silts with (possibly intertidal) peat deposits, these giving way to brackish and eventually freshwater peats"

It is mentioned in Chapter 1 that early Holocene sea levels were higher than those at present, and the Main Postglacial shoreline for Ulva is estimated as c. 10 m O.D. (Dawson, 1984; Ballantyne and Dawson, 1997). Prior to peat formation the basin would be lower than the present 20 m O.D. and could have experienced marine and lagoonal conditions. There are deposits in Livingstone's Cave bog (to the west of the cave at 30 m O.D.) which could be of marine origin as they appear similar to those described by Bonsall *et al.*, (1995). AMS dates suggest that the accumulation of minerogenic materials underlying the mire peat occurred in Lateglacial times (see below) when sea levels were lower (Ballantyne and Dawson, (1997). An adjustment for marine error on dating of 450±50 radiocarbon years (Harkness, 1979; Lowe and Walker, 1984) does not move the dates into the early Holocene.

The minerogenic sediments underlying the organic deposits in the Livingstone's Cave profiles were assessed for their dinoflagellate content (Harland, 1998; Section 2.1.7) in an effort to determine past levels of salinity. The underlying mineral sediments from the A'Chrannag basin were also investigated, as these were visually similar to those from Livingstone's Cave basin. The search for dinoflagellate cysts was unproductive (Harland, 1998) and although sand is not the ideal medium for dinoflagellate preservation, there is no conclusive evidence to indicate that marine conditions were responsible for the sandy accumulations in Livingstone's Cave bog. The current altitude of the mire is c. 30 m OD with a maximum of 3 m of Holocene peats, and, even allowing for erosion of early Holocene sediments and an hiatus (Section 5.3), it is unlikely that early Holocene sea levels would have been sufficiently high to penetrate the area. The similarity between the Livingstone's Cave sediments and those underlying the peat at A'Chrannag basin suggests similar origins, and A'Chrannag basin at 74 m OD must surely be above the range of the early Holocene sea levels. Nevertheless, it is possible that higher sea level in the early Holocene could have increased the salinity of the water table in the Livingstone's Cave basin and this may have had implications for sedimentation and vegetation succession at the site (Sections 5.3.2, 5.5.2).

When combined with AMS dates and pollen evidence (discussed below, Sections 5.3 and 5.5) the above evidence suggests that the lower part of the Livingstone's Cave profiles, underlying the most recent peat, dates to the Lateglacial and is probably not directly of marine origin.

5.3 AMS dates

5.3.1 A'Chrannag bog profiles

A total of six AMS radiocarbon dates was obtained for profile AC1 and two dates for profile AC2 were secured. These are provided in Table 5.1. Age - depth curves for AC1 and AC2 are shown as Figures 5.4 and 5.5

respectively. A diagram of the spread of dates from Ulva at 2 standard deviations is presented in Figure 5.6.

Dates on AC1 confirm that this provides the oldest polleniferous sediments of the two profiles. The lowest date on AC1a of 8625±75 BP (7740 cal. BC) is slightly younger than the succeeding date of 8705±75 BP (7870 cal. BC), although when the standard deviations on each date are considered, both are statistically indistinguishable at the 1σ level (Figs. 5.4 and 5.6). If older minerogenic material was mixed into the peat through erosion then this could account for the reversal in dates, but the contemporaneous LOI percentages are high and there is no indication that erosion occurred. The dated horizons all come from the same core and thus undulating sediment horizons would not explain the reversal in dates. As the next date of 8540±95 BP (7770 cal. BC) on AC1 (at 282 cm) is also very similar to the two preceding dates it is possible that the overlap of the earlier dates is a result of rapid sedimentation (Fig. 5.4) or compaction of peat (cf Aaby, 1986) and the range of statistical error on the earlier dates means that, at 2 standard deviations, the first could be older than the second (Fig. 5.6). In order to calculate pollen influx and sediment depostion rates, the date at the base of the profile AC1, 8625±75 BP (7740 cal. BC) at 304 cm has been used and the later date of 8705±75 BP (7870cal. BC) is discarded as these two dates are virtually the same.

Linear extrapolation suggests that the base of AC2 dates to c. 6500 BP (5460 cal. BC) and peat inception here is far later than at AC1. As AC2 is sited at the southern edge of the bog then it is possible that the infilling of the basin was related to topography, progressing from a depression in the bog centre and outwards to the edges. Although the depth of sediments at AC2 is similar to that at AC1, linear extrapolation of dates suggests that the top of the peat at AC2 is approximately 2500 years old whereas at AC1, the top of the profile is estimated to date to c. 4000 BP (2530 cal. BC) (Figs. 5.4 and 5.5). Although sediment accumulation rates may have varied above the uppermost dates of each profile, the bog surface appears to have been cutover in the past.

The remainder of dates on AC1 and AC2 display no detectable anomalies. Indeed, the expansion of *Ulmus, Quercus* and *Alnus* on AC1 and AC2 is virtually synchronous at 5685±60 BP and 5695±55 BP respectively (both 4530 cal. BC). This suggests that correspondences between the profiles are reliable, despite the apparent late introduction of these taxa to pollen catchment area compared to elsewhere in the Inner Hebrides (see below and cf. Lowe and Walker, 1986; Birks, 1989; Edwards and Berridge, 1994; Chapter 7).

5.3.2 Livingstone's Cave bog profiles

AMS dates were also obtained for the two profiles from the Livingstone's Cave mire; five on LC1 and two on LC2. These are shown in Table 5.1 and as age-depth curves in Figures 5.7 and 5.8. The spread of dates at 2 standard deviations for the Livingstone's Cave cores is included in Figure 5.6.

Profile LC1 has the only dates on what appear to be Lateglacial organic deposits, possibly well humified peats (LC1a, LC2a) which sit beneath an horizon of green sandy clays (LC1b; LC2b). The uppermost organic deposits in LC1a have an estimated date of 11,120±100 BP (11,260 cal. BC) and these probably mark the end of the Lateglacial Interstadial (although the date could be too old if the sediment sampled included a degree of re-worked older material [cf. Edwards, 1990]). The base of the Lateglacial Interstadial organic horizon was dated to 10,760±85 BP (10,770 cal. BC) which is evidently too young and the date is unreliable. The clays overlying the organic deposits in LC1b and LC2b probably accumulated in the Loch Lomond Stadial. An hiatus in sedimentation occurs between the top of the Loch Lomond Stadial clays and the overlying peat within the basin.

The base of the peaty deposits overlying the clay was dated on each of the profiles LC1 and LC2. Despite the similarity of the pollen assemblages in LC1c(i) and LC2c(i), the dates differ by over 2000 years (7765±60 BP (6580 cal. BC) and 5515 ± 55 BP (4350 cal. BC) respectively). Whilst the contamination of the basal peats by the infiltration of rain water and humic acids could have produced dates on both profiles which are erroneously young (cf. Walker, 1984; Edwards *et al.*, 1991) subzones LC1c(i) and LC2c(i) incorporate similar taxa, suggesting a similar date for peat initiation at both core sites.

Either of the dates recorded at the base of the Holocene peats could be correct, therefore two age-depth curves for LC1 and LC2 have been constructed using the dates recorded at the base of each core (Figs. 5.7 and 5.8). When the date of 7765±60 BP (6580 BC) is used for linear extrapolation, the curves for LC1 and LC2 are similar when extrapolated back to the Lateglacial Interstadial dates, although this would assume a continuous and steady rate of sedimentation into the Holocene which is obviously not the case. Ascribing the date of 7765±60 BP (6580 cal. BC) to the base of the Holocene sediments in the Livingstone's Cave basin also means that *Ulmus*, *Quercus* and *Alnus* appear earlier than in the A'Chrannag basin. As *Ulmus* and *Quercus* are introduced to most pollen profiles in the Inner Hebrides and west coast of Scotland by c. 8000 BP (6910 cal. BC) (Birks, 1989; Whittington and Edwards, 1997) this is not especially problematic, but the expansion of *Alnus* in the profiles LC1c(ii) and LC2c(ii) shortly after 7765±60 BP (6580 cal. BC) is earlier than most of the *Alnus* pollen records for the islands although the expansion of this taxon is notoriously asynchronous (Birks, 1989; Chambers and Elliott, 1989; Bennett and Birks, 1990).

An alternative scenario is that the basal date of 5515±55 BP (4350 cal. BC) is the correct date for the inception of peat in the Livingstone's Cave basin. At 2 standard deviations, this date overlaps those on AC1 and AC2 (5685±60 BP and 5695±55 BP (both 4530 cal. BC); Fig 5.6) when *Ulmus, Quercus* and *Alnus* expand. This suggests that from this time the slopes and higher ground surrounding Livingstone's Cave basin could have been wooded with hazel, birch, oak and elm, which could have reduced minerogenic sediment input and promoted the accumulation of humic material and peat formation in the basin. The slopes are not too steep to support woodland cover, as they are covered in a deciduous woodland flora today. Also, if the later date of 5515±55 BP (4350 cal. BC) on LC2c(i) is correct, then reductions in *Ulmus* pollen in LC1c(ii) coincides with those in the A'Chrannag basin, occurring between c. 4800 - 4600 BP (3570 - 3310 cal. BC). Although local ecological factors may have caused the decline of *Ulmus* at different times in the two basins (refer to chapter 7), other reductions in *Pinus* and *Corylus* in the latter parts of LC1c(ii) and LC2c(ii), appear at comparable times according to linear extrapolation if the date of 5515±55 BP (4350 cal. BC) is used, and suggest that this is probably correct. If the date of 7765±60 BP (6580 cal. BC) is used, the the *Pinus* and *Corylus* reductions appear at very different times in each profile.

There is no readily apparent solution as to which, if either, of the dates for the Livingstone's Cave basal peats is correct. Although it is possible that neither is erroneous, the similarities of the Livingstone's Cave pollen profiles suggest that their basal dates should be the same. Confirmation of similarities between subzones LC1c(i) and LC2c(i), and LC1c(ii) and LC2c(ii), is provided in the DCA plot of subzone mean scores (Fig. 5.9). If peat initiation began on a physically disturbed clay surface a mixing of older and younger materials could have produced the different dates. Sedimentation may also have been very slow, and the dates may be the result of averaging for a very thin layer. Contamination, either in the field or laboratory, might also be considered as a factor causing the different dates. As the taxa in the Livingstone's Cave pollen profiles have very different percentages and concentrations to those from A'Chrannag, it is not easy to employ inter-site comparisons. However, if a basal date of 5515±55 BP (4350 cal. BC) is applied to both of the Livingstone's Cave profiles, the expansion of arboreal taxa in the Livingstone's Cave basin matches that in the A'Chrannag profiles, the 'elm declines' correspond between basins, and the comparative reductions in *Pinus* and *Corylus* in LC1c(ii) and LC2c(ii) cover the same timescale. The preferred date for the base of LC1c(i) and LC2c(i) is thus 5515±55 BP (4350 cal. BC) and the main presentation and interpretation of LC1 and LC2 is predicated upon this assumption.

5.4 Presentation and discussion of A'Chrannag pollen data

Percentage, concentration and pollen influx diagrams for both the A'Chrannag profiles are presented as Figures 5.10, 5.11 and 5.14 - 5.17. *Alnus* is excluded from the pollen sum in the Ulva percentage profiles due to the dominance of its pollen in many of the sampled levels, relating to the high pollen productivity of this taxon. Summary diagrams of LOI, charcoal data, TLP concentration and influx and total damaged pollen are shown as Figures 5.12 and 5.13 and damaged pollen percentage diagrams as Figures 5.18 - 5.19. Local assemblage zones and comparisons of profiles AC1 and AC2 are detailed in Table 5.2.

5.4.1 AC1a *Betula*- Cyperaceae - *Filipendula*; AC1b(i) *Corylus* - *Calluna* - *Sphagnum*; AC1b(ii) *Corylus* - Poaceae - Cyperaceae; c. 8700 - 6250 BP (7790 - 5160 cal. BC)

The major pollen types recorded in AC1a are *Betula*, Cyperaceae and *Filipendula*. Other taxa present in low amounts include *Ranunculus acris*-type, *Thalictrum*, *Plantago major/media* and *Rumex acetosa*, in addition to the aquatics *Littorella uniflora*, *Potamogeton natans*-type and *Menyanthes trifoliata*. The assemblage suggests the presence of birch scrub punctuated by open areas dominated by sedges and tall herbs. The presence of aquatic taxa indicates localised wetness and possibly ponding on the mire surface.

In the latter part of AC1a, *Corylus* and *Calluna vulgaris* expand and *Betula* percentages and concentrations slightly decline. Values of Ch:P show substantial increases from low amounts recorded earlier in the zone and suggest that fire may have engineered these taxon changes. *Sphagnum* sprores also increase in the upper part of the zone.

The *Corylus* expansion at A'Chrannag (i.e.a consistent presence > 2 % TLP) shortly before c. 8500 BP (7470 cal. BC), is later than at many of the other sites in the Inner Hebrides (Birks, 1973; Birks, 1989; Edwards and Berridge, 1994; Loch an t'Suidhe, this volume), but is earlier than at Kinloch, Rum (possibly 7800±75 BP (6700 cal. BC); Hirons and Edwards, 1990) and Loch Fada, Skye (7500±120 BP (6330 cal. BC); Birks and Williams, 1983). Nevertheless, the dates for the A'Chrannag *Corylus* expansion correspond with those for other sites on Skye (such as Loch Choira Ghobhain [8650±150 BP (7840 cal. BC), Birks and Williams, 1983]) and from the west of Mull (e.g. Torness, Glen More [8760±140 BP (7900 cal. BC), Lowe and Walker, 1986a; 1986b]). The significance of the spread of dates for the

Corylus rise is discussed in Chapter 7, but the date of c. 8500 BP (7470 cal. BC) for the *Corylus* expansion on Ulva is not untoward.

It is interesting that the rise in *Corylus* coincides with an apparent expansion in *Calluna* heath and increases in charcoal concentrations, influx and Ch:P. Smith (1970) suggested that the postglacial *Corylus* expansion in the British Isles may have been assisted by fires, possibly started by Mesolithic people. This claim has been largely refuted, as microscopic charcoal values usually decline or are low or absent at the *Corylus* rise in most pollen profiles (Edwards, 1990; Huntley, 1993). However, increases in charcoal influx and *Calluna vulgaris* at the *Corylus* rise in AC1a provide a good indication of local fires. Burning may assist the propagation of *Calluna* seedlings and thus the expansion of *Calluna* heath (Hobbs and Gimingham, 1987), and burning at A'Chrannag could be anthropogenic in origin due to people setting fires to create browse for game (Simmons and Tooley, 1981). As *Corylus avellana* is fire tolerant compared to other arboreal species, fires may also have been utilised to promote its growth above other arboreal taxa. *Corylus* is easily coppiced and provides both food and wood suitable for the construction of tools and other domestic uses. However, the north of A'Chrannag bog is relatively exposed, and natural fires may also have arisen from lightning strikes during storms, producing the same effects.

An alternative explanation for the behaviour of *Corylus* at AC1a is migrational lag. Ulva is a small island and although close to Mull, it is separated from it by a channel of deep and turbulent water and high cliffs. Boyd and Dickson (1986) suggest that this as one of the reasons for the late expansion of *Corylus* on Arran. Nevertheless, tidal currents have been suggested as a method by which *Corylus* propagules may spread (Salmi, 1963 cited in Huntley and Birks, 1983). Further discussion of the expansion of *Corylus* in the Inner Hebrides is provided in Chapter 7.

Following the *Corylus* expansion in AC1b(i) there are reductions in the *Corylus* and *Calluna vulgaris* percentage and absolute pollen values between 277 cm and 264 cm (c. 8400 - 7900 BP [7450 - 6810 cal. BC) which coincide with reductions in absolute charcoal values and Ch:P, and increases in *Betula, Osmunda regalis*, Pteropsida (monolete) indet. and *Sphagnum*. The later part of AC1b(i) shows a recovery in values of *Corylus* and *Calluna vulgaris*, but in AC1b(ii) *Corylus* values reduce again although *Calluna* values remain stable. *Betula* percentages and influx values also decrease in AC1b(ii) and are contemporaneous with increases in *Salix, Sphagnum* and *Pteridium*, and Pterposida (mono.) indet. and Cyperaceae in the latter part of the subzone where a temporary reduction in LOI from ~ 90 % to ~ 65 % also occurs. Charcoal influx and Ch:P values remain low in AC1b(ii).

The intial decrease in *Corylus* and *Calluna* in AC1b(i) may be linked to the cessation of fires in the area. The appearance of *Osmunda regalis* and *Sphagnum* in AC1b(i) are indicative of an increase wetness which could have reduced the flammability of local vegetation. If human activity was responsible for the earlier inferred localized burning, then a cessation in fires possibly caused by the out-migration of people from the area would presumably result in lower charcoal representation, and reductions in *Corylus* and *Calluna*. There is no reason why increased wetness itself should have directly reduced *Corylus* populations as hazel is tolerant of damp conditions. Its reduction along with those in the charcoal curves may reinforce the suggestion that early Holocene *Corylus* populations at A'Chrannag may have been influenced by fire.

AC1b(ii) dates from c. 7900 BP (6810 cal. BC) which coincides with the start of a period of climatic cooling in the Atlantic mentioned in earlier chapters (Alley *et al.*, 1997; Barber *et al.*, 1999; Willemse and Törnqvist, 1999). This could be responsible for the further reduction in *Corylus* within this zone, although in contrast to Loch an t'Suidhe, microscopic charcoal values are low. The increases in ferns, willow and *Sphagnum* in AC1b(ii) mentioned earlier suggest a waterlogged environment which may have adversely affected local birch-hazel woodland. High levels of damaged pollen in these subzones may result from pollen trapped in water on the mire surface for some time, or from re-worked pollen washed into the bog by numerous streams which would increase localised waterlogging.

There is no recovery of *Betula* and *Corylus* in AC1b(ii) between c. 7300 - 7100 BP (6190 - 5930 cal. BC) which occurs at Loch a'Bhogaidh and Loch an t'Suidhe, and may be associated with a recovery in temperatures in the North Atlantic. This suggests that if the vegetation reflected in AC1b(ii) is the result of climatic impacts, then the changes were sufficient to prevent any considerable recovery of arboreal species. However, Loch a'Bhogaidh and Loch an t'Suidhe were both lakes, and may have received pollen from a much wider area than the peat filled basin of A'Chrannag whereasAC1b(ii) may reflect local changes.

5.4.2 AC1b(iii) (Poaceae - Cyperaceae - *Sphagnum*), AC1c; AC2a, AC2b; c. 6250 - 5300 BP (5160 - 4150 cal. BC)

In AC1b(iii) the reduction in *Corylus* and *Betula* pollen values continues, but *Salix, Calluna* and Pteropsida (mono.) indet. also reduce. There is a small but temporary increase in *Pteridium aquilinum* within this subzone but the main increases occur in Poaceae, Cyperaceae, *Filipendula*, *Potentilla*-type

and *Succisa pratensis*. There are also increases in microscopic charcoal values within AC1b(iii) particularly Ch:P, although charcoal influx is not high.
In corresponding AC2a *Betula* values are also low and *Corylus* declines from high percentages at the base of the zone as Cyperaceae, Pteropsida (mono.) indet. and *Pteridium* increase. Although Ch:P is high in AC2a. charcoal influx is low and comparable with that in AC1b(iii). A variety of herbs are also recorded in AC2a and include *Aster*-type, *Filipendula, Succisa pratensis* and Apiaceae undiff. *Calluna vulgaris* is also present in this zone.

Very intense burning may have reduced birch and hazel woodland at A'Chrannag, and this could also significantly affect heathland ecology by enforcing a transition to *Pteridium* and then Poaceae (Hobbs and Gimingham, 1987; Legg *et al.*, 1992). Greater increases in microscopic charcoal, particularly charcoal influx, might be expected if such intense local burning had occurred, but unknown taphonomic factors mean that local fires cannot be discounted in reducing the local extent of *Corylus* woodland and heathland at A'Chrannag c. 6250 BP (5160 cal. BC). Low influx values for *Betula* and *Corylus* until c. 5700 BP (4350 cal. BC) in AC1 and AC2 indicate that this woodland was not particularly dense, and the array of herbs recorded in AC1b(iii) and AC2a could occur in natural clearings and on the rocky slopes to the south of A'Chrannag basin. There is evidence from Livingstone's Cave that people were present on Ulva c. 5700 BP (4650 cal. BC). Whilst low charcoal influx suggests that they did not employ fire to clear woodland it is possible that tree felling could have assisted in expanding grassland, possibly to encourage grazing. Certainly grazing pressure can maintain and widen areas herb-rich grassland (Bennett *et al.*, 1992).

Pinus pollen is present in both profiles but in higher percentages and concentrations in AC2a. However this is likely to be a statistical artefact as *Pinus* influx in both profiles is similar. If local, *Pinus* may have inhabited the thinner soils of rocky outcrops surrounding the bog but there are no major differences in damaged (broken) *Pinus* pollen percentages in either AC2a and AC1b(iii) which might indicate local or regional derivation.

Ulmus, *Quercus* and *Alnus glutinosa* expand c. 5750 BP (4590 cal. BC) within the latter part of AC1b(iii) and at the transition to AC2b, with increases in percentages, concentrations and influx. Shortly after this date, at the transition to AC1c, *Betula* displays a marked expansion in percentages, concentrations and influx, and despite percentage reductions, an increase in *Corylus* influx occurs. Calluna, Poaceae, Cyperaceae and herbs are considerably reduced in both profiles in addition to Ch:P and charcoal influx.

It appears that from c. 5750 BP (4530 cal. BC) episodes of local burning may have ceased thus allowing the expansion of woodland over the site. The increase in woodland would also have provided an effective screen to charcoal particulates from further afield. Whilst some heath and grassland habitats may have declined at the expense of woodland the absence of any notable reduction in influx for *Calluna*, Poaceae and Cyperaceae suggests that the percentage and concentration decreases in these taxa is a statistical artefact due to large amounts of arboreal pollen in the assemblages of AC1c and AC2b. Wood macrofossils in the peat of both profiles from c. 5750 BP (4530 cal. BC) (mainly *Alnus glutinosa*) indicate that at least *Alnus* woodland was growing at the bog surface.

Betula, Corylus, Ulmus and *Quercus* influx rates are greater in AC1c compared with AC2b, but *Alnus glutinosa* displays much higher influx rates in AC2b. This suggests that *Alnus* populations were greater to the south of the bog, and a mixed woodland dominated by *Betula* was probably present in the north of the basin. There is also a disparity in percentages of damaged pollen for arboreal taxa between AC1c and AC2b. Total damaged pollen percentages, particularly total pitted percentages, are greater in AC2b, and this may be an indication that the pollen is derived from further afield and not in the vicinity of AC2b. However, *Alnus* influx rates suggest that this taxon was local to AC2b, yet pitted percentages for *Alnus* reach c. 30 % in this zone, compared with c. 20 % in AC1c. The differences in damaged pollen percentages between the profiles may therefore relate to sediment accumulation rates. Slower sediment accumulation at AC2 may mean that pollen was exposed to the atmosphere and surface wet/dry cycles for longer periods of time. The high amounts of *Alnus* compared to other arboreal taxa in AC2b may mean that the south of the bog was particularly wet, and Wilkinson and Huntley (1987) found that pollen may deteriorate faster in bog pools rather than in raised dry areas, although they acknowledge that this conflicts with other evidence (e.g. Dimbleby, 1985; Moore and Webb, 1991). Such pools may contain large amounts of *Sphagnum* which could trap pollen grains and expose them to oxidisation and fungal attack at the pool surface.

At c. 5750 BP (4530 cal. BC), the expansion of *Ulmus*, *Quercus* and *Alnus* in the A'Chrannag profiles is considerably later than recorded for other profiles in the Inner Hebrides. The *Ulmus* expansion is usually anticipated at c. 8500 BP (7470 cal. BC) and *Quercus* shortly after, c. 8000 BP (6910 cal. BC) (Huntley and Birks, 1983; Birks, 1989; Edwards, 1996). The timing of the *Alnus* expansion is notoriously sporadic, but pollen profiles suggest that this taxon was very much established within the Inner Hebrides by c. 6000 BP (4910 cal. BC) (Huntley and Birks, 1983; Birks, 1989). It is possible that the earlier burning of vegetation at A'Chrannag prevented the expansion of these taxa and although an earlier intermittent presence of *Ulmus* is recorded at c. 5% TLP in AC1b from c. 8000 BP (6910 cal. BC), which may reflect a local presence, it is also likely to result from the long distance transport of *Ulmus* pollen, as are the low amounts (< 2 % TLP) of *Quercus* and *Alnus*. The late expansion of these taxa may be related to a fall in sea level around c. 6000 BP (4910 cal. BC) (Ballantyne and Dawson, 1997). This may have meant that the exposed A'Chrannag basin received less salt spray from c. 6000 BP (4910 cal. BC) which may have prevented earlier extensive colonization by the major arboreal taxa. It is noted that arboreal pollen influx at Loch an t'Suidhe on Mull, directly to the south of Ulva, is also low until c. 6000 BP (4910 cal. BC) and this might also be explained by earlier high sea levels and increased salinity restricting woodland species.

Further discussion of the behaviour of these taxa in a wider regional context is presented in Chapter 7.

5.4.3 AC1d *Betula - Calluna*; AC1e(i) *Betula*; AC1e(ii) *Corylus-Calluna*; AC2c(i) *Alnus - Corylus* - Poaceae c. 5300 - 4200 BP (4150 - 2790 BC)

Although greater detail of this time period is offered by AC1 due to better resolution, both profiles show that a mixed woodland of *Betula, Ulmus, Quercus* and *Corylus* was present at A'Chrannag from c. 5300 BP (4150 cal. BC). *Pinus* may have been a minor component of local woodland, or its pollen may derive from further afield on Ulva or nearby Mull (refer to 5.4.2). As with the previous zone, *Betula* influx is greater in AC1 than AC2, but

Alnus influx is greater in AC2 which, assuming a reliable chronology, suggests differences in the local distribution of these taxa.

At c. 5300 BP (4150 cal. BC) in AC1d, *Calluna* percentages and absolute values increase. These coincide with rising charcoal influx, concentrations and Ch:P, and temporary reductions in percentages and concentrations of *Ulmus*, *Quercus* and *Alnus,* although only *Alnus* pollen influx values are reduced. There are no large increases in *Calluna* or charcoal representations from c. 5300 BP (4150 cal. BC) in the comparative zone AC2c(i), but percentages, concentrations and pollen influx values of Poaceae increase and a greater variety of herbs, including *Potentilla, Ranunculus acris-type, Filipendula,* Rubiaceae and Apiaceae undiff., is recorded. *Plantago lanceolata* appears at nearly every level in and fromAC2c(i) albeit in low amounts of < 2 % TLP; this may be an indication of grazing by domestic animals and could signify a human presence. Ch:P could be lower in AC2c(i) compared with AC1d and AC1e, as the latter zones provide better resolution, but is is more probable that the microscopic charcoal recorded represents localised burning to the north and east of A'Chrannag mire.

From c. 5000 BP (3860 cal. BC) in AC1e(i), *Calluna vulgaris* and *Corylus* are reduced and charcoal influx, concentrations and Ch:P values fall, but all increase again in AC1e(ii) from c. 4800 BP (3570 cal. BC). The relationships of the charcoal and *Calluna vulgaris* curves suggest that fires were responsible for increases in heather pollen. It is possible that humans could have intentionally burned heathlands to promote the growth of new shoots suitable for the grazing of livestock and to promote areas of browse for game such as grouse (Hobbs and Gimingham, 1987). The occurrence of a *Hordeum*-type pollen grain in AC1e(ii) at c. 4400 BP (3120 cal. BC) provides potential evidence of cereal cultivation near A'Chrannag, and the base of a pit containing the charred remains of cultivated barley and oats was dated to 4990±60 BP (3730 cal. BC) in Livingstone's Cave. The confirmed presence of Neolithic people reinforces the possibility that fires were used in the management of heathlands on Ulva.

Nevertheless, it is possible that natural fires arising from lightning strikes could also have set heathland alight and Pennington *et al.* (1972) provide evidence for increased rainfall in the British Isles from c. 5200 BP (4010 cal. BC). Seasonal temperatures may also have been lower. If Atlantic storms became more frequent from c. 5200 BP (4010 cal. BC), then this could account for an increase in fires arising from lightning strikes. There are peaks in *Sphagnum* in AC1e(i) and AC1e(ii) which coincide with lower values of *Calluna* and Ch:P and might indicate increased wetness, perhaps due to higher rainfall. If fires were anthropogenic in origin, then increased wetness may have reduced the flammability of *Calluna* heathland and prevented burning between c. 5000 BP (3860 BC) and c. 4800 BP (3570 BC).

There are other indications of a less favourable climate in the A'Chrannag profiles. The AC1 pollen influx profiles display reductions in all arboreal pollen types (including *Corylus*) from c. 5200 BP (4010 BC), and therefore climatic effects could have affected woodland from this time. The number of trees could have been reduced due to increased waterlogging and lower temperatures, flowering may also have been reduced by this and with woodland species becoming more susceptible to disease. If all woodland types were affected, then there would be little change in the pollen percentage data. Increases in *Plantago lanceolata* and herbs in AC2c(i) could be due to reductions in woodland and more soil exposure.

A decrease in *Ulmus* pollen percentages and concentrations is recorded at c. 5100 BP (4010 cal. BC; 178 cm) in AC1d and at c. 4800 BP (3570 cal. BC; 132 cm) in AC1e(i). A decline in *Ulmus* pollen in AC2c(i) from 210cm (c. 4800 BP [3570 cal. BC]) could correspond to either of the declines noted in AC1e(i) due to the potential inaccuracies of the dates, but a simultaneous reduction in *Pinus* pollen percentages and concentrations is noted in AC2c(i) which suggests that it probably corresponds with the secondary decline of AC1e(i). An earlier decline may not be recorded in AC2 due to low pollen influx and taphonomic influences which affect the distribution of pollen across the bog.

Secondary *Ulmus* declines c. 4800 BP (3570 cal. BC) have been recorded in Scotland (Robinson and Dickson, 1988; Edwards and McIntosh, 1988; Edwards and Whittington, 1997), and Northern Ireland (Edwards and Hirons, 1986). Increases in rainfall associated with climatic change as indicated by records for *Pinus* would, in some locations, increase waterlogging, podzolisation and acidification of soils. Falls in seasonal temperatures could also have reduced *Ulmus* populations, particularly those of *Ulmus glabra*, which has greater potential than other species of this genus to colonize poorer soils and greater extremes of slope (Birks and Huntley, 1983) and is most likely to inhabit marginal environments. A peak in *Alnus* pollen after the *Ulmus* decline in AC1e(i) may be a response to wetter conditions at the bog surface and a reduction in LOI indicates the inwash of minerogenic sediments. However, increases in *Corylus, Calluna* and Ch:P increase in AC1e(ii) and *Plantago lanceolata* is recorded shortly after the *Ulmus* decline in AC1e(i). It is possible that this represents human activity which may be linked to the elm decline. However, all the evidence for this occurs after the *Ulmus* decline at A'Chrannag despite dates from the archaeological site confirming that people were present at c. 4800 BP (3570 BC). Additional evidence of *Ulmus* declines on Ulva is presented for Livingstone's Cave profiles, Section 5.5.4 and further discussion of *Ulmus* declines in the Inner Hebrides is made in Chapter 7.

5.4.4 AC2c(ii) and AC2c(iii) *Betula* - *Calluna* - Poaceae - *Potentilla* 4200 - 2500 BP (2790 - 600 cal. BC)

From c. 4200 BP (2790 cal.BC) in AC2c(ii), *Betula* increases in both percentage and absolute values, but there is relatively little change to the *Quercus, Alnus, Corylus* and Poaceae curves. In AC2c(ii), *Potentilla*-type expands to be consistently present in values > 2 % TLP. Charcoal is not recorded at every level and charcoal influx and Ch:P are low, and there is no indication that substantial burning occurred locally which could indicate human activity. However, the sustained presence of *Plantago lanceolata* in AC2c(ii) may represent the effects of grazing of domestic animals, and suggests a continuous human presence near the site. The zone dates to the late Neolithic and Early Bronze Age, when pastoral activity was well established (Simmons and Tooley, 1981; also cf. Edwards and Ralston, 1996). The transition to AC2c(iii) is marked by an anomalous spike in *Alnus* pollen percentages and absolute values, but the overall pollen assemblage changes little from AC2c(ii). Most notable is the presence of an *Avena-Triticum*-type pollen grain in a sample dating to c. 2800 BP (1000 cal.BC) which might indicate that mixed farming was taking place.

5.5 Presentation and discussion of the Livingstones Cave Bog profiles

Percentage, concentration and pollen influx diagrams for the two profiles from Livingstone's Cave bog, LC1 and LC2, are presented in Figures 5.20, 5.21 and 5.24 and 5.27. Summary diagrams of LOI, microscopic charcoal, TLP concentrations, pollen influx and TD% for each profile are presented as figures 5.23 - 5.24 and damaged pollen percentages as figures 5.28 and 5.29. Table 5.3 compares (sub)zones between the Livingstone's Cave profiles.

5.5.1 LC1a Cyperaceae - *Cichorium intybus*-type; LC2a Cyperaceae; c. 11,000 - 10,000 BP (11,050 - 9530 cal. BC)

The pollen assemblages LC1a and LC2a are dominated by Cyperaceae and *Cichorium intybus*-type (probably *Taraxacum officinale)*, and Poaceae and *Parnassia palustris* pollen is also present. The pollen is representative of an open, damp environment which is likely to have incorporated other taxa not recorded in the pollen profiles. Much of the pollen in this zone may be reworked, as suggested by a potential reversal in dates (Fig. 5.6, Table 5.3.) although these may be similar at 2 SD. If re-working of sediment had taken place then higher percentages of damaged pollen might be expected, and TD% does not exceed 5 % for most of the zone. Although high Ch:P might indicate high levels of reworked charcoal (cf Edwards and Berridge, 1994) charcoal could also derive from the fallout of large amounts of aerial particulates in a virtually treeless environment, and low pollen concentrations may augment Ch:P values. Charcoal influx in LC1a and LC2a is low, but higher than in the later Holocene profiles. In the absence of re-working then the low levels of *Betula, Pinus* and *Corylus* pollen (< 2 % TLP) could indicate the local paucity of woodland taxa, or long-distance transport of pollen during the Lateglacial Interstadial.

LOI reaches ~ 70 % in LC1a, but does not exceed ~ 20 % in LC2a and low sediment accumulation rates are indicated (although these are unreliable as they are based on extrapolation from dates on later Holocene sediments which does not allow for an hiatus in sedimentation).

5.5.2 LC1b and LC2b (No pollen) c. 10,000 - 5500 BP (9530 - 4380 cal. BC)

Zones LC1b and LC2b are characterised by a decrease in LOI to < 5 % and a change in stratigraphy to green sandy clay. The inorganic sediments yielded insufficient pollen to allow a reliable vegetational reconstruction, thus there is no pollen represented in these zones on the diagrams. Of the little pollen present, most was severely corroded and crumpled, making identification difficult. However, it was noted that Cyperaceae pollen dominated the lower levels of LC1b and LC2b. This could possibly result from intermixing with underlying organic sediments or the reworking of older polleniferous horizons from elsewhere. The samples from the upper levels of the zones contained the pollen of Cyperaceae, Poaceae, *Betula,* possibly *Rumex* sp., and what may be Caryophyllaceae undiff. or *Thalictrum*. *Sphagnum* was also present in apparently large quantities in many samples, suggesting damp conditions. Although not quantified, microscopic charcoal was also noted in many of the samples, and high levels are recorded in many Lateglacial pollen profiles (cf. Edwards, 1978; Whittington *et al.*, 1991a; Edwards and Berridge, 1994). Iron sulphate spherules suggesting wet conditions, possibly ponding (Wiltshire *et al.*, 1991), were also present in most samples.

LC1a and LC2b are probably of Loch Lomond Stadial date from c. 11,000 to 10,000 BP (11,050 - 9530 cal. BC).

5.5.3 LC1c(i) *Corylus* - Cyperaceae and LC2c(i) *Corylus* - Cyperaceae; c. 5515 - 5350 BP (4350 - 4160 cal. BC)

The base of the peat overlying the Lateglacial mineral sediments has radiocarbon dates of 5515±55 BP (4350 cal. BC) and 7765±65 BP (6580 cal. BC). Although the later date is preferred, both dates suggest a discontinuity of sedimentation within the basin stratigraphy and it is possible that the erosion of early Holocene sediments could have taken place.

Although tidal activity due to marine incursion into the basin could also have removed early Holocene sediments, this has already been dismissed (Section 5.2). It is most probable that sedimentation in the basin was absent for the earlier Holocene. Although the indication of ponding and waterlogging by spherules in the later mineral sediments underlying the Holocene peat suggests extremely wet conditions, subsequent drying of the relatively porous, sandy sediments could have prevented the expansion of vegetation into the basin, or the preservation of organic detritus. Although there is no clear evidence that an hiatus in sedimentation occurred in the Livingstone's Cave bog profiles, it is the most plausible explanation of the basin stratigraphy.

Subzones LC1c(i) and LC2c(i) represent the earliest polleniferous Holocene sediments in the Livingstone's Cave basin. In these subzones, both LOI curves rise steadily, signifiying the accumulation of peat over earlier sandy clays. *Corylus*, *Salix*, Cyperaceae and Poaceae are recorded in both subzones, with a variety of herbs including *Filipendula*, Apiaceae undiff., Brassicaceae, *Potentilla*-type and *Ranunculus acris*-type. The presence of *Calluna vulgaris*, *Vaccinium*-type and Emptrum nigrum in LC1c(i) and LC2c(i) suggests a heathy type flora at the bog surface. *Alnus glutinosa* rises from low values at the base of LC1c(i) but does not expand until the succeeding subzone in LC2, and it may be that LC2c(i) is slightly earlier than LC1c(i). Ch:P and charcoal influx are greater in LC1c(i) than LC2c(i) but falls tocomparativelylow levels towards the end of the subzone. The differences may be explained if LC1c(i) dated slightly earlier than LC2c(i), or if a greater degree of mixing with the underlying Loch Lomond Stadial deposits had occurred in LC1c(i).

The pollen spectra indicate that c. 5500 BP (4380 cal. BC) the mire surface vegetation consisted of areas of sedge-dominated grassland with a tall-herb flora and pockets of *Salix* scrub and heath. *Alnus* and *Corylus* may not yet have been locally present; low percentages and influx in the early profiles suggest that these taxa were relatively sparse.

Pinus sylvestris pollen is also recorded in LC1c(i) and LC2c(i). Although its percentage representation reaches between 15 - 20 % TLP, low influx values suggest that it was probably not present at Livingstone's Cave bog. Indeed, the sparsely wooded environment would have allowed the influx of *Pinus* pollen transported from further afield.

5.5.3 LC1c(ii) *Ulmus - Quercus - Alnus – Corylus* and LC2c(ii) *Ulmus - Quercus - Alnus - Corylus;* c. 5350 - 4900 BP (4160 - 3730 cal. BC)

At the transition to LC1c(ii) and LC2c(ii), LOI values increase to ~ 90 % and this value is maintained for the duration of the subzone. *Corylus* and *Alnus* are the predominant taxa in percentage terms, although their pollen influx values remain low, averaging 20,000 grains cm^{-1} yr^{-1}, compared to those in A'Chrannag basin averaging 50,000 grains cm^{-1} yr^{-1} for the same period. This suggests that woodland in Livingstone's Cave bog was sparse. Nevertheless, *Alnus* macrofossils in the peat stratigraphy show that this taxon was present at the mire surface. Although a slightly earlier presence of *Ulmus* was recorded in subzone LC1c(i), the main expansion of *Ulmus* and *Quercus* occurs in LC1c(ii) and LC2c(ii). At an estimated date of 5200 BP (4010 cal. BC) this is slightly later than recorded in the A'Chrannag profiles c. 5600 BP (4500 cal. BC) but the dates for both basins overlap at 2 SD. *Betula* persists in LC1c(ii) and LC2c(ii) in similar percentages to those recorded in the previous subzone.

Despite the range of percentage values recorded for *Betula, Ulmus, Quercus* and *Corylus*, pollen influx values are similar for these taxa (within each profile and between the LC profiles). This may indicate that their pollen derives from a wide area, possibly further afield than Ulva, or that none was predominant over the others within the local woodland flora. However, *Alnus* influx values are higher than for the other arboreal taxa, and this taxon was undoubtably of greater local abundance at and probably around the mire surface as is indicated by *Alnus* macrofossils in the peat.

The range of herbs recorded in the earlier subzones is reduced in LC1c(ii) and LC2c(ii) and both *Salix* and *Calluna* decline to values of < 2 % TLP. although increases in ferns are recorded. The expansion of *Alnus* onto the Livingstone's Cave mire may represent increasingly wet conditions which may not have suited *Calluna* heath. *Salix* may have persisted locally as an understorey shrub, but its pollen was not widely distributed, therefore it is not present in the pollen record and a damp understorey of sedges and ferns would have been present. *Betula* may also have intermixed with *Alnus* and *Corylus* at the mire surface but *Ulmus* and *Quercus* were probably more abundant on the better drained soils at the basin edges.

Microscopic charcoal is virtually absent in LC1c(ii) and recorded only in very low values in LC2c(ii). Most of the charcoal is probably background charcoal rain and higher representations in LC2c(ii) may derive from the fallout of airborne particles reaching the eastern slopes at the mire edge.

In the latter part of LC1c(ii) (from 290 cm) and from early in LC2c(ii) (from 280 cm), the *Alnus, Pinus*, and *Corylus* curves display reductions in percentage, concentration and influx values and a reduction in *Ulmus* occurs in LC1c(ii). Although an *Ulmus* decline appears in LC2c(ii) this is the result of being unable to achieve reliable pollen counts between 241 and 243 cm on this core , so part of the pollen record is missing. The actual reductions in arboreal pollen in LC1c(ii) and LC2c(ii) coincide with increases in Cyperaceae and ferns, and in LC2c(ii) Poaceae values also increase. Ch:P remains low in both LC1c(ii) and LC2c(ii), although there are two independent spikes in Ch:P within LC2c(ii). The LOI percentages of both profiles appear constant. The reductions in arboreal pollen in both profiles occur c. 5100 BP (4010 cal. BC) if the estimated chronology is correct which is also the date for the classic British *Ulmus* decline. which has been attributed to climatic deterioration (cf. Whittington *et al.*, 1991b; Walker and Lowe, 1985 and Chapter 4, Loch an t'Suidhe; Hirons and Edwards, 1986). If the distribution of woodland species assumed above is correct, it appears that the local vegetation of the mire surface was affected which implies that changes in mire conditions probably caused the reductions in the taxon profiles. Whether these resulted from the effects of a changing climate (i.e. increased rainfall) or other local factors (such as the change in drainage patterns or bog growth) cannot be determined.

There are also reductions in *Alnus* and *Corylus* in the A'Chrannag profiles AC1 and AC2 at a similar time to those above (estimated c. 5200 BP [4010 cal. BC]), and in AC1d, these appear to be linked to increases in burning and the propagation of *Calluna* heath. If this was the result of human activity, then the arboreal pollen reductions in LC1c(ii) and LC2c(ii) could also result from this. However, large amounts of *Alnus* macrofossils in the peat in both cores indicate low levels of humification which could be linked to waterlogging. Within LC1c(ii) and LC2c(ii) pollen influx values and concentrations are very low and, at some sampled levels, this resulted in preparations with insufficient pollen to produce reliable counts. LC1c(ii) in particular contains high amounts of pitted pollen which has been linked to wet-dry cycles (Wilkinson and Huntley, 1987; Campbell and Campbell, 1994). TD% for the complete LC1 profile is higher and more sporadic than for LC2, suggesting that the central mire area experienced greater extremes of wet-dry cycles than the eastern mire edge. Thus the reduction in arboreal pollen in LC1c(ii) and LC1c(ii) may be the result of a period of increased wetness in the mire and/or increased wet-dry cycles at the mire surface. The spikes in Ch:P in LC2c(ii) could derive from the inwash of charcoal fragments of possible secondary origin. Increased rainfall due to climate change may have contributed to the possible hydrological changes in Livingstone's Cave bog, but these could also be a result of the natural cycles of mire growth affected by its morphology and environmental setting.

5.5.5 LC1c(iii) *Alnus* - *Corylus* - Cyperaceae; LC2d(i) and (ii) *Alnus* - *Corylus* - Poaceae; LC2e(i) *Betula* - *Alnus* - *Corylus* - Poaceae

c. 4900 - 4000 BP (3730 - 2530 cal. BC)

This period is covered by LC1c(iii) and in greater resolution by LC2d and LC2e(i). Sampling in LC1c(iii) was interrupted by several *Alnus* macrofossils between 225cm and 238 cm in the core, and there is no pollen record for this section of the profile.

LC1c(iii) and LC2d(i) incorporate a similar pollen assemblage to that of the previous (sub)zones, where *Alnus, Corylus*, Poaceae, Cyperaceae and ferns are the main components and *Alnus* and *Corylus* values recover from the reductions noted earlier. Although a contraction in *Alnus* is suggested in LC2d(i), this arises from an anomalous spike in *Alnus* percentages and absolute values at the base of this subzone, and when compared to the previous zone, LC2c(ii), no real reduction is indicated. *Calluna* is virtually absent from LC1c(iii) and LC2d(i), and this may signify that the mire was particularly waterlogged (hence the predominance of *Alnus* in the percentage profiles). A greater variety of herbs is recorded compared to the earlier subzones, and includes Apiaceae undiff., *Potentilla* and *Filipendula*. These indicate that woodland at the mire surface was not particularly dense, and that clearings of damp grassland and tall-herbs were present. Ch:P values increase within LC1c(iii) and LC2d(ii) (even with increases in TLP concentrations) although charcoal influx remains low. Such increases in charcoal could also result from sparse woodland cover, and may signify increased openings in local woodland. Low charcoal influx suggests that extensive burning was unlikely, and increases in Ch:P could derive from increased aerial fallout if screening woodland was reduced. A human presence on Ulva from c. 4990 BP (3730 cal. BC) is confirmed by dates on artefacts from Livingstone's Cave and at this time people may have intentionally removed areas of woodland for fuel, or to provide areas for cultivation. Grazing by domestic animals may also have opened up woodland in the Livingstone's Cave basin. Nevertheless, the pollen may also represent natural openings in woodland on the bog surface, and woodland does not appear to have been particularly dense according to pollen influx data.

The main feature of LC1c(iii) is a second decline in *Ulmus* pollen at 270 cm c. 4800 BP (3570 cal. BC) which corresponds with the timing of the *Ulmus* declines in the A'Chrannag profiles. This is accompanied by a marked reduction in LOI over a single level from 95 % to 15 % and increases in *Pteridium aquilinum*, Ch:P and charcoal influx. As LOI values recover c. 4650 BP (3450 cal.BC), *Ulmus* percentages resume those previously recorded. *Ulmus* declines occur at 240 cm c. 4600 BP (3440 cal. BC) in LC2d(i) and at 220 cm c. 4200 BP (2790 cal. BC) in LC2d(ii) following a large increase in *Ulmus* percentages and absolute values at 235 cm c. 4400 BP (3120 cal. BC). Given the unreliable dating of the Livingstone's Cave profiles, it is possible that either of the elm declines correlate with that on LC1c(iii) at 270 cm c. 4800 BP (3570 cal. BC).

The causes of the *Ulmus* declines in the Livingstone's Cave profiles from c. 4800 BP (3570 cal.BC) may have an underlying climatic cause as suggested for the A'Chrannag profiles, but disease may also have been a factor in temporarily reducing *Ulmus* populations on Ulva and variability in the distribution of pathogens may explain the potential spatial and temporal distributions of the *Ulmus* declines in the profiles.

Consideration must also be given to the potential for human influence on *Ulmus* populations from c. 4800 BP (3570 cal. BC). The increases in Ch:P, *Pteridium aquilinum* and in herbs, particulary *Potentilla* (possibly *P. erecta*) in LC1c(iii) and LC2d(ii) could suggest that burning occurred locally, although this appears unlikely given the low charcoal influx in both profiles. Nevertheless, Livingstone's Cave was inhabited in the Neolithic from c. 4990 BP (3730 cal. BC) (Bonsall *et al.*, 1995) and people may have expanded open areas of woodland for cultivation or grazing. A possible *Hordeum*-type pollen grain in combination with increases in *Plantago lanceolata* in LC2d and an *Avena-Triticum*-type grain in LC1c(iii) reinforce the evidence for a human presence, and from c. 4400 BP (3120 cal. BC) there is evidence in A'Chrannag bog (AC1e(ii)) that fire may have been employed in the management of *Calluna* heath. It is therefore possible that people could also have influenced local *Ulmus* populations. The gathering of leaves and the stripping of bark and branches alone could have reduced *Ulmus* but this would have exacerbated effects arising from any climatic influences and rendered trees prone to disease. If *Ulmus* was an important resource to Neolithic people, then its decline could also have been prompted by some form of management, perhaps coppicing (cf Hirons and Edwards, 1986), which could increase flowering and could therefore be the cause of the temporary increase in *Ulmus* c. 4400 BP (3120 cal. BC) at 235 cm in LC2d(ii).

There is no clear evidence, however, for human involvement in the *Ulmus* declines at Livingstone's Cave bog, and climatic and edaphic influences would be expected to influence the behaviour of *Ulmus* in the Ulva profiles. The complexity of interpretation surrounding the *Ulmus* declines is extremely evident in the above and further discussion of the *Ulmus* declines on Ulva is provided in Chapter 7, in the context of the wider Inner Hebridean region.

Following the *Ulmus* declines and the interruption of LC1c(iii) by *Alnus* macrofossils, after c. 4100 BP (2660 cal. BC) *Alnus, Betula, Ulmus, Quercus* and *Corylus* and ferns persist in similar percentages and absolute values to those recorded earlier. However, in the later part of LC1c(iii) *Filipendula* and *Potentilla*-type are recorded in low values, and *Silene vulgaris*-type is also present reaching maximimum values of c. 5% TLP. A grain of *Avena-Triticum*-type in the latter part of LC1c(iii) c. 4100 BP (2660 cal. BC) and could reflect cultivation in the catchment area. Other anthropogenic indicators are rare, however, in the pollen profiles and grasses and herbs remain low in percentage and absolute terms. This suggests that cultivation may have taken place some distance from the pollen site, or the *Avena-Triticum* type grain represents a wild species of grass, possible wild oat.

At the transition from LC2d(ii) to LC2e(i) c. 4100 BP (2660 cal. BC), a single *Hordeum*-type grain coincides with increases in *Plantago lanceolata, Pteridium aquilinum* and Ch:P. *Plantago lanceolata* and *Pteridium* persist within the LC2e(i) profile where an expansion in *Betula* percentages is recorded and a further *Hordeum*-type grain occurs later in the zone. The indication from LC2e(i) is of increasing human activity in the vicinity of Livingstone's Cave basin. Although the cereal-type pollen grains could derive from wild grasses, carbonized macrofossils of *Hordeum* sp. and *Avena* sp. have been recovered from deposits within Livingstone's Cave which may be contemporary with the pollen profiles in these subzones, suggesting that cultivation on Ulva occurred in the Neolithic. The increases in herb pollen, particularly *Plantago lanceolata* in LC2e(i), indicate open areas within the woodland, and vegetation succession within these could be indicated by increases in *Betula*, a frequent secondary pioneer taxon. The greater amount of evidence for human impacts appears in LC2e(i). This is probably due to the location of core LC2 at the bog edge, close to the known site of human occupation. LC2 is also closer to better drained areas above the mire which may have been cultivated and is also located at the foot of slopes to the east which may have been grazed by domestic animals.

5.5.6 LC1d *Alnus - Corylus*; LC1e *Betula* - Poaceae - *Potentilla*; LC2e(ii) *Betula* - Cyperaceae - *Filipendula*

4000 - 3200 BP (2530 - 1480 cal. BC)

The period of 4000 - 3600 BP (2530 - 1950 cal. BC) is represented by LC1d, LC1e and LC2e(ii). The earlier part of LC2f covers the later period 3600 - 3200 BP (2530 - 1480 cal. BC). Between c. 4000 and 3600 BP (2530 - 1950 cal. BC), LC1d displays marked increases in *Alnus* and *Corylus* pollen percentages and influx values, whilst *Pinus* almost disappears from the profile. This is representative of the regional *Pinus* decline evident in other pollen profiles from western Scotland (cf. Bennett, 1984; Hirons and Edwards, 1990; Willis *et al.*, 1998) linked to an increasingly wet climate. The increases in *Alnus* could therefore be a response to increased wetness at the mire surface and the higher *Corylus* values may actually reflect an expansion in *Myrica gale*. Although Edwards (1981) suggests that *Myrica* is not a significant component of *Corylus avellana*-type pollen in Scotland until c. 2000 BP (100 cal. BC), the data are limited to a few sites in eastern Scotland. The warmer oceanic climate of the Inner Hebrides may have favoured an earlier expansion of *Myrica*, which thrives in wet conditions, and the behaviour of many taxa on Ulva does not conform to established precedents (e.g. the expansion of *Quercus* and *Ulmus*). *Myrica* twigs and leaves were also recovered from peat from Machrie Moor, Arran in significant amounts dating from c. 3500 BP (1820 cal. BC) (Robinson and Dickson, 1988).

Other arboreal taxa of *Betula, Ulmus* and *Quercus* are still present in LC1d, and Poaceae and Cyperaceae are represented in high values. *Calluna vulgaris* and *Lonicera periclymenum* also increase in LC1d, although percentage and absolute values are relatively slight, and there is a peak in Ch:P although charcoal influx is very low. If this represents a fire event, then it may be linked to the increase in *Calluna* within this zone. The presence of *Lonicera* suggests that an opening may have occurred in the local woodland canopy, but this may be a natural occurrence and is not necessarily the result of human activity. Nevertheless, human actions could be the source of burning and increase in *Calluna* represented in LC1d.

From c. 3800 BP (2220 cal. BC) in LC1e there are marked reductions in percentages and absolute values of *Alnus, Corylus, Ulmus*.and *Quercus* which coincide with increases in *Betula* and Poaceae. *Lonicera* is high at the base of this zone, and *Calluna* is also recorded in values similar to the previous zone. There is a greater abundance and range of herbs which include *Filipendula*, *Potentilla*-type, *Plantago lanceolata*, *Rumex* spp., *Ranunculus acris*-type andApiaceaeundiff. Noticeable peaks in Ch:P also occur and a small increase in charcoal influx. In LC2e(ii), *Alnus* and *Corylus* values decrease, and *Ulmus* is present in very low amounts. A similar range of herbs to those in LC1e is recorded, and in the latter part of LC2e(ii) charcoal influx and Ch:P increase.

Pollen assemblages in LC1e and LC2e(ii) intimate that from c. 3800 BP (2220 cal. BC) an intensification of human activity resulted in the reduction of much of the woodland in the pollen catchment area, creating areas of *Betula* scrub and herb rich grassland. Wood may have been collected for domestic purposes, and for grazing animals, and grazing itself would have assisted in maintaining open areas.

5.5.7 LC2f *Alnus* - *Corylus* - Poaceae; 3200 - 2600 BP (1480 - 670 cal. BC)

From c. 3200 - 2600 BP (1480 - 670 cal. BC), zone LC2f, *Alnus* and *Corylus* recover from previous values, and Poaceae increases, but fewer herb pollen taxa are evident. Nevertheless, Ch:P remains high and charcoal influx increases to a profile maximum. Two incidences of *Hordeum*-type pollen are recorded. Despite a recovery in local woodland, human activity may have persisted near the site, and the mire edge location of LC2 may have enabled this to be detected. However, this pollen assemblage may also indicate an increase in wetness in Livingstone's Cave bog and the *Corylus* recorded in this zone may represent *Myrica gale* at the mire surface as discussed above. The *Hordeum*-type pollen grains recorded in LC2f may therefore be large grass pollen such as *Glyceria fluitans* which prefers a wet environment, and

Poaceae pollen is abundant in this zone. *Alnus* is also tolerant of wet conditions, and Ch:P values may have been maintained by inwash down the slopes to the east of the core site. However, Ch:P values are comparable to those in the earlier zone which suggests that human occupation did not entirely disappear from Ulva after c. 3200 BP (1480 cal. BC). Indeed, a shift in the location of human activity could have cleared vegetation elsewhere and consequently increased runoff into the Livingstone's Cave basin at LC2. An amalgamation of natural and human factors probably influenced the local vegetation between c. 3200 BP (1480 cal. BC) and 2600 BP (670 cal. BC).

5.6 Contrasts between bogs

Although the pollen profiles from A'Chrannag and Livingstone's Cave bogs extend to cover different periods of time, all the profiles cover the period c. 6000 - 4200 BP (4910 - 2790 cal. BC). Within this period, the profiles indicate variations in local vegetation within and between basins.

5.6.1 General observations

A series of maps indicating the spatial variations in inferred vegetation patterns on Ulva between c. 8500 and 4000 BP (7470 and 2530 cal. BC) are presented as Figures 5.30 - 5.33.

In A'Chrannag basin from c. 8500 - 6000 BP (7470 - 4910 cal. BC) (Fig. 5.30), *Corylus* is the dominant arboreal taxon. *Calluna vulgaris* seems to have been prevalent to the northwest of the bog, and charcoal records in AC1 suggest fires, either natural or anthropogenic, influenced episodic *Calluna* growth, and may also have favoured *Corylus* and prevented the expansion of other arboreal taxa. Birch scrub was also prevalent to the northwest of A'Chrannag basin, and may have been interspersed with *Calluna* heath.

Shortly after c. 6000 BP (4910 cal. BC) *Quercus, Ulmus* and *Alnus* expand but percentage and pollen influx curves indicate that *Alnus* populations were greater to the south of the bog, perhaps because the environment here was wetter or less exposed. There is relatively little *Alnus* recorded in AC1, where *Betula* dominates the pollen profiles, perhaps due to the degree of exposure to south-westerly winds experienced by the north of A'Chrannag bog, *Betula* being able to withstand this better than other arboreal taxa.

From c. 5500 BP (4380 cal. BC) in the Livingstone's Cave basin, *Salix* and herb-rich grassland were replaced by *Alnus-Corylus* woodland. *Alnus* may have been the dominant taxon in the basin according to pollen percentages, but *Alnus* influx is very low compared with A'Chrannag, and high values of Poaceae, Cyperaceae and herbs suggest that the basin was wetter and woodland more open than A'Chrannag.

TLP and charcoal influx in the A'Chrannag basin are much higher than at the Livingstone's Cave sites, and damaged pollen percentages are greater in the lower bog profiles. This may be an indication of the differences in bog growth and hydrological characteristics. Peat formation in the A'Chrannag basin progressed earlier than in the Livingstone's Cave basin and the former mire probably developed raised bog characteristics. In contrast, the younger Livingstone's Cave basin peats may have been rheotrophic, or at the transition to mesotrophic status (Moore *et al.*, 1991), and more waterlogged than those in the A'Chrannag basin, deriving more nutrients from runoff and streams. The different bog statuses would have influenced vegetation patterns, but differential peat accumulation and hydrological characteristics could have implications for the deterioration of pollen grains. Wilkinson and Huntley (1987) find that pollen preservation may be considerably worse in wetter areas of bog where TLP concentrations are also low, and that better preservation and higher TLP concentrations often occur in drier, hummocky areas dominated by *Calluna* heath. This would seem to be borne out by the evidence from the Ulva basins.

Charcoal influx is much lower in Livingstone Cave profiles than in the A'Chrannag profiles. This is a possible reflection of the distribution of fires, and the high amounts of *Calluna* in the AC1 profile may result from burning. A'Chrannag bog may also have been drier and its vegetation more easily combustible than that in the Livingstone's Cave basin.

5.6.2 The expansion of arboreal taxa

The major expansion of arboreal taxa (*Quercus, Ulmus* and *Alnus*) in the A'Chrannag profiles takes place c. 5600 BP (4500 cal. BC). A similar expansion occurs in the Livingstone's Cave profiles and, if the dates assumed for the base of the Holocene sediments in LC1 and LC2 are correct, this also takes place c. 5600 BP (4500 cal. BC). This expansion is late compared with those at other Inner Hebridean sites (e.g. Loch a'Bhogaidh, Islay; Loch an t'Suidhe, Mull; Gribun, Mull [Walker and Lowe, 1987]) and pollen isochrone records for western Scotland (Huntley and Birks, 1983). Although small island ecologies may differ from those in mainland areas and the larger islands, it is unlikely that this could explain the late expansion of arboreal taxa on Ulva, and given the earlier expansion of *Quercus* and *Ulmus* c. 7800 BP (6640 cal. BC) at remote sites in neighbouring Mull (Torness and Coire Claccach in Glen More, Walker and Lowe, 1985) it is unlikely that the high cliffs and fast flowing channels of water which separate Ulva from Mull could have significantly delayed the transport of propagules.

As the Holocene basal dates for the Livingstone's Cave bog profiles may be incorrect, *Quercus, Ulmus* and *Alnus* could have expanded earlier than 5600 BP (4500 cal. BC) at the site (possibly c. 7700 BP [6600 cal. BC]) although severe wetness in the mire floor could have delayed and restricted their expansion in comparison to other Inner Hebridean sites.

If an earlier woodland expansion occured in the Livingstone's Cave catchment, then it is not easy to explain a much later woodland expansion at the A'Chrannag catchment. It is possible that the date of 5685±60 BP (4530 cal. BC) in the A'Chrannag profiles is also incorrect, and that woodland expanded earlier than this in the A'Chrannag catchment. However, it is possible that the A'Chrannag basin was strongly favourable to birch-hazel woodland and *Calluna* heath, and that frequent fires, whether of natural or anthropogenic origin, assisted in maintaining this form of vegetation at the expense of other woodland taxa.

The problematic dates on the Ulva profiles make interpretation of woodland expansion in the areas of the A'Chrannag and Livingstone's Cave basins difficult, and there is no single reason which readily explains the possible delay in the arrival of *Quercus, Ulmus* and *Alnus* in the two basins. An amalgamation of many factors is probable, and underlies the complex nature of the ecology of Holocene arboreal colonisation.

5.6.3 The *Ulmus* profiles

The *Ulmus* percentage profiles from both the Ulva basins are presented with cereal-pollen and charcoal profiles in Figure 5.34a. *Ulmus* influx curves are presented in Figure 5.34b. *Ulmus* influx is slightly higher in the A'Chrannag than in the Livingstone's Cave profiles, and the more exposed A'Chrannag site may have received greater amounts of airborne pollen transported for long distances. It is also possible that the drier environment of the A'Chrannag basin compared to the Livingstone's Cave basin was more favourable to *Ulmus*.

In the A'Chrannag profiles an *Ulmus* decline occurs in AC1 c. 5100 BP (4010 cal. BC) and a later decline occurs in AC1 and AC2 c. 4800 BP (3570 BC) where the taxon is reduced to virtual absence appears in each profile. Multiple *Ulmus* declines appear in the Livingstone's Cave profiles as early as 5100 BP (4010 cal. BC) and as late as 4200 BP (2790 cal. BC) although the taxon persists until c. 3800 BP (2220 cal. BC) in LC1. Various interpretations were suggested for these differences, including the effects of climate and disease combined with ecological and edaphic factors. The sheltered nature of the Livingstone's Cave basin may have provided better conditions for *Ulmus* compared to the exposed A'Chrannag basin so that edaphic conditions could have moderated the effects of climatic deterioration or pathogenic attack. Indeed, *Ulmus* populations around the sheltered Livingstone's Cave basin may have been less susceptible to disease if their environment was more favourable. Grace (1987) states that south facing and sheltered slopes may be 3°C warmer in summer than north facing slopes, which may be equivalent to a latitudinal difference of a hundred kilometres of more. Hence the effects of conditions on *Ulmus* in the different Livingstone's Cave and A'Chrannag basins could have been significant.

Human influence on *Ulmus* populations was also suggested but the indications of human activity in all the Ulva profiles occur shortly after the *Ulmus* declines. If Ulmus in the A'Chrannag catchment had suffered the impact of disease, then subsequent clearance of this taxon by Neolithic people may have contributed to its continued absence in the later profiles. The suite of data from the Ulva profiles indicates that Neolithic people may have burned vegetation to create or maintain areas of heathland, and cleared woodland for grazing animals and for cultivation from as early as c. 5200 BP (4010 cal. BC).

Scanning for early cereal-type pollen in contiguous 1cm samples means that the earliest cereal-type pollen in the Ulva profiles is probably detected. Cereal-type pollen occurs shortly after the *Ulmus* decline at AC1, and, although Ch:P is also high, earlier peaks in Ch:P occur where *Ulmus* was constantly present, and the charcoal probably relates to the burning of heathlands. At AC2 there is no cereal-type pollen connected to the *Ulmus* decline when Ch:P falls. In the initial *Ulmus* decline c. 4800 BP (3570 cal. BC) in LC1 there is a small increase in Ch:P but this is not substantial and may result from the fallout of fires to the north of A'Chrannag.

Whilst the pollen and charcoal evidence suggests that people could have modified vegetation communities on Ulva from the Mesolithic, and that such activity may have intensified into the Neolithic, there is no evidence to directly link human actions with the demise of *Ulmus* in the A'Chrannag and Livingstone's Cave basins up to c. 4800 BP (3570 BC). A later *Ulmus* decline which coincides with declines in other arboreal taxa recorded in LC1 c. 3800 BP (2220 cal. BC) may be linked to human actions as other arboreal taxa decrease at the same time whilst herbs and Ch:P increase. Nevertheless, the impacts of climate change and disease in the context of site location and its characteristics were probably the most influential factors in the *Ulmus* decline on Ulva.

5.6.4 **Human impact** (Refer to Figs. 5.30 - 5.33)

The Ulva pollen profiles show that very different vegetation communities existed around the A'Chrannag and Livingstone's Cave basins in the early

Holocene and the effects of human activity are also spatially different. Between 8500 and 7000 BP (7470 - 6010 cal. BC) there is evidence that to the northwest of the A'Chrannag basin, burning of *Calluna* heathland occurred. In the south of the basin, from c. 6200 - 5700 BP (5090 - 4350 cal. BC), charcoal in AC2 may be the fallout from fires in the northwest or could represent local burning. The pollen indicates that openings occurred in local *Corylus-Betula* woodland, and possibly resulting from the felling of trees through burning. If these different pollen assemblages are the result of human impacts, they may represent different land usage, or they may be the result of similar activities on different areas of vegetation.

Later in the profiles from c. 5300 BP (4150 cal. BC), AC1 shows further evidence of fire which may be linked to the expansion of *Calluna* heathland. This again coincides with increases in herbs in AC2. The first possible evidence of cereal cultivation occurs c. 4600 BP (3440 cal. BC) in AC1 and coincides with a reduction in charcoal and *Calluna*, which may indicate a temporary change in Neolithic land use, from heathland management to crop production. Cereal-type pollen is detected in the other profiles at later dates (Section 5.6.3) from c. 4200 BP (2790 cal. BC) and coincides with reductions in arboreal pollen, expansions in herbs (including *Plantago lanceolata*) and increased charcoal influx. Charcoal records suggest that burning was much greater in the vicinity of AC1 and Mesolithic and later Neolithic communities may have set fires to refresh areas of heathland. To the south of A'Chrannag (AC2) and to the west of the Livingstone's Cave basin (LC2), temporary reductions in trees may indicate that people occasionally cleared small areas for cultivation, or to use wood for domestic purposes. The grazing of domestic animals may also have caused openings in the woodland.

5.6.5 Summary

The Ulva pollen profiles show that a range of vegetational communities may have occurred over a relatively small area of c. 2km^2 in southeast Ulva. If the dates on the Ulva profiles are correct, the timings of the expansions of the major arboreal taxa do not correspond with existing pollen isochrone and isopollen patterns (Huntley and Birks, 1983; Birks, 1989) and indicate that small island ecologies may be very different to those on larger islands and the Scottish mainland. The Ulva profiles also include indications of human impacts from as early as the Mesolithic period, but evidence of human disturbance increases into the Neolithic, and frequent occurrences of cereal-type pollen suggest that arable cultivation was undertaken.

CHAPTER 6 - RUM: ANALYSIS OF POLLEN FROM KINLOCH.

6.1 Site description

The Farm Fields pollen site (Figure 6.1; Plate 6.1), NGR NM 399 399, is located 500 m west of the Farm Fields area of excavation, close to the mouth of the Kinloch River at Loch Scresort. At 10 m O.D. the site is comprised of soligenous peat deposits formed over a raised beach platform of sandstone sloping gently north to south. Transects undertaken by Hirons and Edwards (1990) and for this research showed that the peat varied from 0.5 m to 1.8 m deep. To the north and east of the site are areas of planted woodland made up of *Alnus glutinosa*, *Corylus avellana*, *Quercus* spp., *Pinus sylvestris* and *Sambucus nigra*. *Salix* spp. saplings are present on the peat itself but these are small and growth is checked by grazing animals. Trampled areas around the field boundary display vegetation characteristic of disturbed ground such as *Plantago lanceolata, P. coronopus* and *Rumex acetosella.* The mire surface includes a range of Poaceae and Cyperaceae, plus *Equisetum* spp., Rubiaceae, *Filipendula ulmaria, Potentilla erecta, Ranunculus acris* and a variety of orchids. *Sphagnum* spp. are common in the wetter areas.

6.2 Background to the present study

Initial surveys of the area by Hirons and Edwards (1990) located the deepest parts of the peat (Fig. 6.2) and subsequent pollen analyses from two monoliths, K and KII (Fig 6.1), showed that K was suitable for intensive study; the pollen in KII was severely degraded and much of it was unidentifiable. Subsequent depth probing in the location of K showed that peat depths varied between 0.40 m and 1.10 m on an east-west transect, whereas on the north-south transect the maximum peat depth found was 0.60 m, and the peat was occasionally interrupted by clusters of stones. The east-west line was therefore determined the most suitable for sampling (Fig. 6.3). Sampling positions to the west of existing fields and to the south of former cultivation ridges in the surrounding slopes and to the east and west of site K were thought likely to provide a 'three-dimensional' assessment of vegetation change. It was intended to obtain several monoliths at regular intervals along the transect for comparison with K. Monolith extraction was limited however, as subsurface water rapidly flooded some of the pits, and the positions of these are shown in Figure 6.3. The position of the original profile K (Hirons and Edwards,1990) was either not located or the surface had sunk as a result of drainage or the settling of the large inspection pit excavated in Hirons and Edwards (1985), as depth measurements over much of the site did not record peat deeper than 1.10 m

Further to the work of Hirons and Edwards (1990), three monoliths, KL1, KL3 and KL4, (see Section 2.3.1) were extracted from the Farm Fields site (Figs. 6.1, 6.2). The locations of KL1 (NGR 401 999), KL3 (NGR 399 999), KL4 (NGR 400 999), Hirons and Edwards's (1990) K (NGR 401 999) and the excavated area of human occupation are shown in Figure 6.1. Surface samples (Figs. 6.4 - 6.7) were obtained from each new profile location.

Percentage pollen diagrams of selected taxa for K, KL1, KL3 and KL4 including peat lithologies are shown in Figures 6.8 - 6.11 and concentration diagrams are presented in figures 6.13 - 6.15. Summary diagrams of LOI, microscopic charcoal, TLP concentrations and TD % pollen for KL1, KL3 and KL4 are provided in figures 6.12 and 6.16 - 6.18 and damaged pollen percentages for KL1, KL3 and KL4 are shown as Figures 6.19 - 6.21. Radiocarbon dates for the original profile K and for the new profiles are shown in Table 6.1.

6.3 Reconstruction of vegetation history at Kinloch using profile K (Hirons and Edwards, 1990)

The pollen data from monolith K at Kinloch (Hirons and Edwards, 1990) provided a general vegetation history for the site and strong evidence of local anthropogenic impacts. The pollen spectra indicate that tree cover was not extensive in the early Holocene between c. 7800 and c. 6500 BP (6640 - 5460 cal. BC); *Corylus* was probably the main arboreal taxon. Hirons and Edwards (1990) suggested that the establishment of hazel scrub at the site from c. 7800 BP (6640 cal. BC) is reflected in zone KIa, in which the pollen of Cyperaceae and spores including *Equisetum*, *Osmunda*, *Sphagnum*, and ferns (Pteropsida (monolete) indet.) reflect a damp ground flora. Tall-herb communities are also represented by the pollen of *Filipendula*, *Rumex acetosa* and Apiaceae.

Alnus glutinosa was established around 6500 BP (5460 cal. BC) whence a reduction in the pollen and spores indicative of damp environments suggests progressive drying. During the main phase of *Alnus*-dominated woodland there are two major reductions in arboreal pollen defined by subzones KIIb and KIId. Simultaneous increases in microscopic charcoal may represent phases of burning instigated by human activity, and given the known proximity of Mesolithic people to the pollen site, this explanation has at least equal validity to one of natural causes (cf. Hirons and Edwards, 1990).

The predominance of *Alnus glutinosa* in the pollen assemblage is reduced c. 3950 BP (2440 cal. BC) and is accompanied by increases in Poaceae, Cyperaceae and herbs, notably *Potentilla* (zone KIIIa). A single cereal-type pollen grain was recorded at the base of zone KIIIa, and *Plantago lanceolata* and *P. major/media* are present. Charcoal concentrations also increase in this zone, either as a result of increased local fire frequencies or the reduction of the screening effect of woodland to the fallout of airborne charcoal (Hirons and Edwards, 1990), but there is strong evidence for Neolithic impacts. However, climatic deterioration c. 4000 BP (2530 cal. BC) could also have instigated reductions in arboreal taxa, particularly those existing in marginal environments such as are found on Rum. Nevertheless, the strength of the cultural indicators in the pollen profile K indicates that human impacts could at least have exacerbated the ecological effects of climate change.

Throughout zone KIII the dominant taxa are Poaceae and Cyperaceae, and the presence of cereal-type pollen associated with the pollen of ruderal taxa from c. 1500 BP to the present implies a period of continous cultivation. Reductions in LOI during KIIId are likely to reflect increased soil erosion associated with agricultural activity and relict cultivation ridges are visible in the present landscape (Hirons and Edwards, 1990; Wickham-Jones, 1990a).

6.4 Comparison of KL1, KL3 and KL4 with K

It was mentioned in Section 2.2 that the monolith profiles KL1, KL3 and KL4 were not sufficiently deep to provide a record of Mesolithic age vegetation for comparison with K although the deepest peat on and around the transect was sampled. However, there are characteristics in all the pollen profiles which may be attributable to Neolithic activity. In the later pollen profiles, spatial differences are evident which may highlight the need for multiple profile studies, and may also demonstrate the potential use of damaged pollen in their intepretation.

The zonation of pollen diagrams KL1, KL3 and KL4 identifies changes reflecting general vegetation successions at Kinloch which corresponds with major zones in Hirons and Edwards' (1990) original core K. Subzones identify what appear to be localised vegetational differences. The local pollen assemblage zones of each profile are shown in Table 6.2 and Figure 6.23 links comparable assemblage zones between the different profiles.

High levels of *Alnus glutinosa* pollen in KL1a(i), KL3a and KL4a indicate that the profiles post-date c. 6500 BP (5460 cal. BC) when compared with K, and dates of c. 3900 BP (2430 cal. BC) on the earliest cereal-type pollen grains in KL1 and KL4, which coincide with the reduction in *Alnus,* suggest that the inception of polleniferous deposits at KL1 and KL4 is not much earlier than this, and perhaps date to c. 4500 BP (2370 cal. BC). KL3a(i) displays much higher values of *Alnus* pollen than KL1a and KL4a(i), in addition to higher values of *Filipendula*, ferns and Ch:P. This pollen assemblage is similar to that of KIId which, by extrapolation, dates from c. 5200 BP to c.4800 BP (4010 - 3570 cal. BC), and suggests that KL3a(i) is older than KL1a and KL4a(i).

Following the reduction in woodland evident in all the profiles, Poaceae and Cyperaceae dominate the pollen assemblages and a variety of herbs are represented including *Filipendula, Succisa pratensis*, Brassicaceae *and Plantago lanceolata.* Cereal-type pollen was detected in all the profiles at various levels. It is probably better represented in K (Hirons and Edwards, 1990) as the complete profile was subjected to low power scanning for cereal-type grains as part of this project. On the other profiles, this technique was limited to detecting the earliest possible cereal-type pollen around the woodland decline, and not used in the later sections of the profiles.

6.5 Differences between profiles

Although the pollen profiles from all monoliths at Kinloch are similar in their representations of local vegetation, from c. 5000 BP (3860 cal. BC) in K and KL3 and from c. 4000 BP (2530 cal. BC) in KL1 and KL4 as discussed above, Section 6.4, there are small scale differences in the pollen recorded between monoliths (and denoted by the subzones of each profile) which require explanation and may assist in the reconstruction of local environmental changes at Kinloch.

6.5.1 The potential for an hiatus in KL1

In KL1, the transition KL1a - KL1b(i) displays large and marked reductions in the percentages of *Alnus* followed by *Corylus* pollen, a sudden decrease in *Lonicera* pollen and marked increases in Poaceae and Cyperaceae. This compares with the other profiles K, KL4 and KL3, where *Alnus* and *Corylus* display apparently prolonged and more gradual reductions. However, all the concentration profiles indicate steep reductions in *Alnus* in what are considered to be contemporary horizons between the profiles, (KL1a - KL1b, KL4a(i) - KL4a(ii), KL3a(ii) - KL3b and KIIe - KIIIa), although the reduction is perhaps slightly less marked in KL3a(ii) - KL3b. Evidence of a change in lithology or LOI values could be expected in KL1a(i) if an hiatus had occurred. Although a decrease in LOI values and temporary change in lithology to grey sandy silt occurs in KL1b(i), this is after the major decline in arboreal pollen and there are no lithological or LOI changes in any of the profiles at the actual decline.

There are radiocarbon dates for two of the four profiles (KL1 and KL4) around the decline in arboreal pollen, as this coincides with the earliest detected cereals at Kinloch. A date may also be extrapolated for this feature on K. Thus the decline in woodland begins before 3840 ± 45 BP (2330 cal. BC) in KL4a(ii), but woodland persists in the profile until shortly after this. The woodland decline at KL1a occurs at at 3950 ± 60 BP (2430 cal. BC). Both these dates compare favourably with c. 3950 BP (2440 cal. BC) at the start of the arboreal pollen decline at K. Although there is statistical overlap at 2 SD of each date, there may remain a hint that woodland decline at KL1 began earlier than in the other profiles.

The amalgamation of concentration, lithological and radiocarbon data thus suggests that no major hiatus in sedimentation occurred in KL1. It is probable that the differences between the percentage profiles reflect the variability in pollen deposition between the profiles and woodland appears to have declined earlier in the vicinity of KL1 than in the other profiles (see below, 3.3.4). Differential sediment accumulation and pollen influx rates between the profiles could also have contributed to the patterns in the percentage and concentration profiles, and these remain undetected as there are insufficient radiocarbon dates for pollen influx calculations in KL1, KL3 and KL4.

6.5.2 The pollen assemblage prior to reduction of woodland at c. 3950 BP (2440 cal. BC) Zones KL1a, KIId, KIIe, KL4a(i) and KL3a(i) and (ii)

6.5.2.1 KL3a(i) and KIId

Prior to c. 3900 BP (2440 cal. BC) on all profiles, the pollen record indicates that mainly *Alnus* and *Corylus* woodland was present at Kinloch. KL3a(i) is earlier than the basal zones KL1a and KL4a(i) and probably correlates with the earlier part of KIId (discussed above; section 3.3). Sub-zone KL3a(i) represents a woodland flora dominated by *Alnus* and *Corylus*, where *Betula* and *Pinus sylvestris* were probably minor components. As *Pinus* averages c. 20 % TLP for this subzone, then it is likely that the pollen is of local origin and not aerially transported from further afield. It could also be expected that the long distance transport of *Pinus* pollen grains would produce an even distribution across the site, and in the later sub-zone KL3a(ii), *Pinus* appears in greater percentages and concentrations than in the other profiles, again suggesting that *Pinus* was locally present to the west of Kinloch.

Poaceae, Cyperaceae, *Filipendula* and ferns could be present in the pollen subzone assemblages due to the proximity of the site to the Kinloch River and may represent a damp environment. They may also be indicative of woodland clearings and it is possible that these areas were extended by human activity as Ch:P levels are high in KL3a(i), and in KIId. However, KL3a(i) and KIId may not be contemporary and KL3a(i) could be of later date and both sub-zones could reflect extremely local impacts on woodland by prehistoric people at different times.

6.5.2.2 KL1a, KL4a(i), KL3a(ii) and KIIe

In KL1a, KL4a(i), KL3a(ii) and the latter part of KLIIe, the profiles indicate the continued local presence of *Alnus glutinosa* and *Corylus*, and of *Pinus* in KL3a(ii). However, percentage representations of arboreal taxa in the profiles vary. Slightly higher arboreal pollen percentages are recorded in KL1a, but concentrations of these taxa are higher in KL4a(i) and KL3a(i). In contrast, concentrations of Poaceae appear much greater in the later part of KL1a. In KIIe, pollen concentrations overall are at least 10 times greater than those in the subsequently sampled profiles.

Although it is acknowledged that concentrations may not be a reliable comparator as their calculation does not take into account sedimentation rates, the differences in concentrations between the profiles could suggest that, even prior to the reduction in *Alnus* and *Corylus* woodland represented in the later zones, woodland was perhaps sparser in the vicinity of KL1 compared to west of this profile. Indeed, a more diverse woodland is represented in KL3a(ii), where *Betula, Quercus* and *Pinus sylvestris* pollen has comparatively greater values in both percentage and concentration terms.

Although varying sediment accumulation rates and pollen influx may account for some of the disparities in pollen concentrations within the profiles, there nevertheless appear to have been spatial differences within woodland composition at Kinloch according to the pollen data. There is no indication that localised burning could have reduced woodland at KL1a, as Ch:P is low in all profiles. However, KL1a includes high values (10 % TLP) of *Lonicera periclymenum* pollen which is hardly present in the other profiles (values do not exceed 2 % TLP). As *Lonicera* is insect-pollinated (Grime *et al.*, 1988) and produces low amounts of large, heavy grains which will rarely travel far from source. The taxon also requires substantial amounts of light to flower (Grime *et al.*, 1988), thus the abundance of its pollen in KL1a probably reflects an opening up of woodland in this vicinity. The pollen of *Ilex angustifolium* and *Hedera helix*, also understorey taxa which require light to flower, also occur in KL1a. Although the pollen of all these understorey taxa may have derived from the erosion of woodland soils to the north and upslope of the narrow mire, openings in woodland to the north of KL1 would also be required for the flowering of these taxa and for any substantial erosion to occur.

The spatial representations of woodland in the Kinloch profiles prior to c. 3900 BP (2370 cal. BC) indicate that trees were sparse .o the east of Kinloch, close to the known site of human occupation. The earlier reduction in woodland cover and comparatively low arboreal pollen sum recorded in KL1a may therefore be linked to woodland clearance, possibly to open up areas for cultivation or to obtain wood for domestic use.

6.5.3 Reduction of *Alnus-Corylus* woodland c. 3900 BP (2440 cal. BC) KL1b, KIIIa, KL3b, KL4a(ii)

At the transition to KL1b(i), KL4a(ii), KL3b and KIIIa a reduction in percentages and concentrations of arboreal pollen is evident. This appears more marked in KL1, and at 3840 ± 45 BP (2330 cal. BC) in KL4b(i), and at c. 3900 BP (2440 cal. BC) in KIIa, much higher values of *Alnus* and *Corylus* are recorded compared to KL1, where woodland is substantially reduced at 3950 ± 55 BP (2430 cal. BC). Although there is no confirmatory date for the woodland decline in KL3, there nevertheless remains an indication that woodland decline to the west of the Kinloch site was comparatively late.

Alnus glutinosa macrofossils are present in the peat of monoliths KL3b and KL4b(i) but not in KIIIa and KL1b(i). In KL1b(i) there is a significant reduction in LOI from 90 % to 70 % and grey silty peat was recorded in the lithology. A similar horizon of silt particles occurs in the lithology of K between 67 cm and 73 cm and although small reductions in LOI appear in KL3b, there is nothing as significant. The reduction in LOI and the presence of silt particles in K and KL1 are symptomatic of the erosion of minerogenic material from the slopes to the north of the mire. If a greater proportion of woodland was reduced to the east and north of the site (as the pollen and lithology may be suggesting), then more eroded material would be expected to be introduced to deposits to the east of the mire.

Data relating to damaged pollen in the profiles may also be significant to interpretation. Unfortunately thereareno damaged pollen data available for K. There are no significant differences in TD% between the profiles, even when *Pinus* is excluded (as this pollen type breaks easily and may distort figures). Nevertheless, the percentage of damaged (mainly pitted) arboreal pollen types is greater in KL1b, where *Alnus* pollen is 60 - 80 % pitted and *Corylus* pollen 20 - 50 % pitted compared with c. 20 - 30 % pitted for each taxon in KL4a(ii) and KL3b. Total damaged pollen percentages may be affected by local factors affecting pollen preservation, and a greater amount of Poaceae and Cyperaceae pollen is damaged in KL4a(ii) and KL3b. However, greater damage to arboreal pollen in KL1 may mean that this is derived in part from upslope locations. Increases in the ratio of damaged to undamaged arboreal pollen also occur in KL1b compared with KL4a(ii) and KL3b.

It is possible that the reduction in woodland from c. 3950 BP (2440 cal. BC) occurred due to increased wetness at the site and Hirons and Edwards (1990) mention that increased storminess in the Atlantic could have caused this. High amounts of Cyperaceae in all profiles following the main decline in woodland are indicative of a damp environment but there are few other indications of increased wetness. In KL1b(i), *Sphagnum* spores increase and *Succisa pratensis* is recorded at around 5 % TLP for most of the subzone, but not in any of the other profiles. This localised reflection of wetness may be linked to the erosion of slopes to the north of KL1 and associated runoff and increased waterlogging in the east of the mire.

Human activity may also be considered as a factor influencing woodland decline at Kinloch c. 3950 BP (2440 cal. BC). Hirons and Edwards (1990) suggested that human actions will at least have augmented the effects of climatic change. The reduction in woodland coincides with the appearance of early cereal-type pollen at K, KL4a(ii) and KL1b. It is possible that the cereal-type pollen is in fact large-sized Poaceae pollen, possibly that of *Glyceria fluitans,* but there is other circumstantial evidence supporting the case for cereal cultivation on Rum. As arboreal pollen is reduced and Poaceae and Cyperaceae become the predominant pollen types, *Plantago lanceolata* pollen increases in KL1b(i) and KL3b and the grazing of domestic animals could have been responsible for this (cf. Newell, 1988; Bennett *et al.*, 1990). The pollen assemblage includes Brassicaceae, *Rumex acetosella, Succisa pratensis and Ranunculus acris*-type, all taxa which correspond with Hicks' (1988) suggested barley (*Hordeum*) field flora. Cereal-type pollen of Neolithic date was found on pottery shards recovered during the excavation (Moffatt, 1990) also suggesting that cereal cultivation occurred at Kinloch.

Increases in Ch:P in KIIIa and KL1b may also reinforce the case for human activity. As there are no contemporaneous increases in Ch:P in KL4a(ii) and the earlier part of KL3b, microscopic charcoal appears to be concentrated towards the east of the pollen site transect and closest to the area of excavation and known human occupation. This pattern is also reflected in the pollen assemblages. It was mentioned above that KL3b and KL4a(ii) incorporated a greater number of woodland taxa than KIIIe and KL1b. In contrast, percentages of *Calluna vulgaris* pollen are greater in KIIIa and KL1b and this species was also discovered as pollen and macrofossil evidence in contexts from the archaeological site of Neolithic date (Wickham-Jones, 1990). *Calluna vulgaris* heaths are easily combustible, either by human action or natural events, but burning of heathlands in prehistory may have occurred as a form of management (Edwards *et al.*, 1995, Stevenson and Birks, 1995; Whittington and Edwards, 1997a).

High levels of *Lonicera periclymenum* present in KL1a, whilst possibly relating to natural openings in woodland, are perhaps more likely to be a reflection of an opening of the woodland at this point by humans, and a decrease in LOI in KL1b(i) reflects erosion likely to result from the exposure of the surface of slopes to the north.

Whilst climatic deterioration may have contributed to the reduction in woodland throughout the region, the accumulation of evidence at Kinloch suggests that activities linked to human occupation can best explain vegetation changes in the area. The pollen profiles and lithologies suggest that the focus of impact during the final stages of reduction in woodland, c. 3950 BP (2440 cal. BC), was to the east and northeast of the site which is closest to the known area of Neolithic occupation.

6.5.4 The post woodland decline flora from c. 3900 BP (2440 cal. BC) KL1c, KIIIb, KL3c, KL4c

Following the woodland decline, the profiles become dominated by Poaceae and Cyperaceae pollen, which indicates a wet grassland environment. Some herbs are present, particularly the cultural indicators Brassicaceae, *Plantago lanceolata* and *Rumex acetosa* which, in all profiles, frequently coincide with occurrences of cereal-type pollen. This implies that the Kinloch area was at least episodically cultivated from the Neolithic to the present. Ch:P values are high compared to the earlier zones when tree cover was greater. Microscopic charcoal may originate from increased local burning due to human activity (Edwards, 1990) or may be the result of increased microscopic charcoal fallout due to the removal of the fringing woodland.

Low levels of the pollen of *Alnus* and *Corylus* in all profiles indicate a sparse but continuous presence of woodland within the region. An expansion in ericaceous pollen in KIIIb is interpreted by Hirons and Edwards (1990) as representing the colonization of drier sandy soil around the mire by heathland vegetation following the removal of hazel scrub. Little ericaceous pollen is recorded in any of the new Kinloch monoliths, but small increases in *Calluna vulgaris* and *Vaccinium*-type pollen in KL1c, KL3c and KL4c may reinforce this interpretation.

Increases in *Pinus* pollen appear at the top of the profiles in KL1c(iii), KL4c(iii), and KL3c(iii), and probably represents recent conifer plantation around the Kinloch area.

Although the later profiles do not fall within the range of early human impacts, there are variations in the later pollen spectra which are worthy of interpretation.

6.5.4.1 *Alnus* increase, KL3c(ii), KL1c(ii)

An increase in percentage values of *Alnus glutinosa* pollen occurs within KL3c(ii) and KL1c(ii) but this is not seen in profiles K or KL4. It is assumed that these zones are contemporaneous and concentrations of *Alnus* are higher in KL3c(ii). The LOI profiles are consistently high at around 98 % so there is no indication of erosion and the associated influx of minerogenic material to the mire surface at this time. However, the deposits of KL1c(ii) contain *Alnus glutinosa* wood fragments which do not appear in the other monoliths. This suggests that a regeneration of *Alnus* woodland occurred in the locality of KL1 despite less *Alnus* pollen being recorded here compared to KL3c(ii).

It is possible that the mechanisms of distribution of *Alnus* pollen mean that little is deposited within or near the woodland itself. Vuorela (1973) notes that *Alnus* pollen is easily transported above the woodland canopy and quickly distributed by wind action away from wooded areas. It is not impossible that a similar effect may occur for all arboreal pollen as the surface samples from Kinloch (figs. 6.4 - 6.7) indicate that those towards the centre of the mire surface and away from areas of woodland to the north and east of the site show the greatest amounts of arboreal pollen. However, *Alnus* pollen fallout is substantial and Vuorela (1973) found that in surface samples from cultivated fields close to woodland, *Alnus* pollen was to be found in similar values regardless of distance from source. If *Alnus* woodland was located either to the east or west of the bog as the subzones KL3c(ii) and KL1c(ii) suggest, then the airborne redistribution of pollen from these areas should result in a recovery of *Alnus* percentages and concentrations in profiles KII and KL4.

There is no indication in the damaged pollen records to suggest that pollen was better preserved at any of the profile positions in the bog. Total damaged pollen percentages are similar in all profiles where damaged pollen is recorded, and similar percentage damage to *Alnus* grains occurs in both KL1c(ii) and KL3c(ii). If damaged pollen is not a significant factor in explaining the recorded differences between profiles, than it is possible that fast sediment accumulation rates and low pollen influx and sampling resolutions have resulted in the omission of the *Alnus* rise from KL4c and KIIIa or b profiles.

A further consideration in explaining the differences is that the *Alnus* profiles reflect a patchy local distribution of *Alnus*. It is noted that *Corylus avellana*-type pollen increases in conjunction with *Alnus* pollen in KL3c(ii) whereas elsewhere it maintains steady low levels consistent with a continued regional presence. Therefore, it is also likely that regeneration of *Alnus* - *Corylus* woodland to the west of the site, either in the more fertile Kinloch Glen, or on the slopes to the northwest, resulted in an increased input of these pollen types to the west of the mire. Only *Alnus* appears to have been present in KL1c(ii) to the east.

In both subzones KL3c(ii) and KL1c(ii) there are also increases in Ch:P, and cereal-type pollen and ruderal species are detected. *Calluna vulgaris* and *Vaccinium*-type pollen increase in profiles at KL1c(ii), KL4c(i) and KL3c(ii), but particularly in KIIId as mentioned above (Section 6.5.4). The increase in heathland pollen types may be directly related to burning of either natural or human origins and this may also have caused the temporary expansions in *Alnus* and *Corylus* pollen in the outlying profiles as it has been suggested that expansions in *Alnus* and *Corylus* may occur after fire (McVean, 1956a; 1956b). However, *Alnus* is also recorded as a source of wood for the production of charcoal (Brown and Barber, 1985) and it may have been been coppiced alongside *Corylus*. This may also account for high levels of Ch:P and increases in woodland within KIIIb, KL3c(ii) and KL1c(ii).

The overall evidence suggests that *Alnus* and *Corylus* woodland was re-established at the mire edges. Pollen preservation factors are unlikely to be responsible for the different pollen profiles and the paucity of *Alnus* in the pollen record at KL1c(ii), despite the presence of its macrofossils in the lithology of this subzone, may be explained by taphonomic factors and the aerial distribution of pollen away from its source. Different rates of sediment accumulation and pollen influx may explain the absence of a recovery in *Alnus* and *Corylus* pollen in K and KL4, but very local representations of these taxa and restricted pollen distribution could also explain the variations between the different Kinloch profiles.

6.5.4.2 Cereal-type pollen and anthropogenic indicators in the later profiles

There are variations in the timing of occurrences of cereal-type pollen and associated cultural indicators between the cores. Although the inherent problems of the detection of cereal-type pollen (i.e. restricted dispersal; low pollen production) mean that it may not always be detected, even when low-power scanning of samples is employed, the distribution of cereal-type pollen between profiles and the occurrences of ruderal species associated with cultivation, may provide an indication of the area under cultivation.

It was mentioned earlier that cereal-type pollen is recorded alongside the temporary recovery in *Alnus* pollen. A single grain of cereal-type pollen is recorded in KL1c(ii) and two grains in the latter part of KL3c(ii), and these coincide with increases in Brassicaceae, *Plantago lanceolata* and *Ranunculus acris*-type pollen. Brassicaceae and *Plantago lanceolata* are particularly evident in KL3c(ii). Cereal-type pollen is recorded at nearly every sampled level in KIIIb, although *Plantago lanceolata* is more frequently recorded than other flora associated with cultivation. The family Brassicaceae consists of mainly insect-pollinated species (e.g. *Cardamine pratensis, Sinapsis arvensis*) whose pollen is unlikely to be distributed far from original sources whereas *Plantago lanceolata* is wind-pollinated and its pollen may travel some distance. The consistent presence of Brassicaceae and *Plantago lanceolata* in KL3c(ii) suggests that cereal cultivation was very local. The absence of cereal-type pollen and lower instances of ruderal species in KL4c may be a function of detection methods, but may also reflect the distance of this profile from areas of cultivation. KII, KL1 and KL3 are all nearer the bog edge and thus were probably closer to areas of cultivated land.

6.6 Summary of the Kinloch data

The palaeoenvironmental evidence from Kinloch shows that woodland at the site was drastically reduced from c. 3950 BP (2440 cal. BC) and replaced by a damp open flora dominated by Poaceae and Cyperaceae. Localised erosion and flushing of the mire surface may also have occurred. Cereal-type pollen in K, KL1 and KL4 and the corresponding presence of anthropogenic indicators in some of the profiles suggests that woodland reduction was at least partly linked to human impacts, which originally appears to have been concentrated to the east of the site, close to a known area of Mesolithic and Neolithic human occupation.

Cereal cultivation continued throughout the post-Neolithic period until the present day although areas under cultivation may have varied through time. A temporary recovery in *Alnus* and *Corylus* woodland occurs in KL3c(ii) following the earlier woodland decline and a similary recovery in *Alnus* occurs in KL1c(ii). Increases in anthropogenic indicators, Ch:P and Ericaceae coincide with the woodland recovery in both these profiles, and heathland may have expanded in response to management.

Differences in the pollen between monoliths may be interpreted as the result of a complex interplay of taphonomy, local ecological variations, pollen preservation and mire hydrology. Despite this complexity, a multiple profile reconstruction at Kinloch has produced a more detailed picture of Neolithic human activity and subsequent environmental changes on and around the site than was available from the original single monolith. However, the need for a suite of radiocarbon dates in multiple profile studies is highlighted, as these would allow the estimation of sediment accumulation and pollen influx rates, and result in more confident comparisons and interpretations of the profiles.

CHAPTER 7 - SYNTHESIS OF POLLEN DATA FROM THE INNER HEBRIDES, OUTER HEBRIDES AND WEST COAST OF SCOTLAND

7.1 Introduction

The preceding chapters presented pollen diagrams from various sites in the Inner Hebrides spanning the period c. 10,000 BP to c. 2500 BP (9530 - 600 cal. BC). The following summarizes data covering the Mesolithic and Neolithic periods and compares them with other pollen evidence from the Inner and Outer Hebrides and the west coast Scottish mainland.

7.2 Early Holocene Vegetation in western Scotland

7.2.1 The early Holocene c. 10,000 BP (9530 cal. BC)

A summary of published data concerning the composition of early Holocene vegetation in the Inner Hebrides was provided in Chapter 1, Section 1.3. This and the data acquired from the new pollen profiles fits the general precedents indicated by isopollen maps for the Inner Hebrides (Huntley and Birks, 1983; Birks, 1989). Early in the Holocene, c. 10,000 BP (9530 cal. BC) the inferred vegetation at Loch a'Bhogaidh and Loch an t'Suidhe was juniper and willow scrub, with birch forming localised copses, and open areas of herb-rich grassland. This vegetation is similar to that indicated for Skye (Birks, 1973; Williams, 1977; Lowe and Walker, 1991) and north and south central Mull, although *Empetrum* heath appears to have been present in the Glen More area (Lowe and Walker, 1986a and b; Walker and Lowe, 1985, 1987) and probably had a localised presence in many other parts of the islands at this time. At Loch Cholla on Colonsay, in the south-west of the Inner Hebrides, early Holocene vegetation appears to have been composed of birch woodland and sedge-rich grassland.

The woodland in the Inner Hebrides c. 10,000 BP (9530 cal. BC) was initially dominated by *Betula,* but *Corylus* is the next arboreal taxon to be found in most profiles and in many cases it undergoes a rapid expansion to become the predominant taxon in percentage terms (e.g. 50 - 80 %). This is reinforced at Loch a'Bhogaidh by much higher influx rates for *Corylus* than other arboreal taxa between c. 9000 and 8000 BP (8225 - 6860 cal. BC), although pollen influx rates at Loch an t'Suidhe and A'Chrannag are similar for *Corylus* and *Betula,* suggesting that in western Mull and Ulva these taxa were present in similar quantities. The timing of the *Corylus* expansion may vary, and possible reasons for the various timings of the expansion of *Corylus* are discussed below.

The early Holocene vegetation assemblages and successions of the Inner Hebrides compare closely with those for western Scotland although the number of well-dated sites with Holocene pollen records on the western mainland is restricted. A pollen profile from Drimnagall, on the Scottish mainland east of the Isle of Jura (Rymer, 1977), and pollen profiles from Racks Moss and Aros Moss on the Kintyre peninsula to the south of Drimnagall (Nichols, 1967) suggest that birch woodland was established in the early Holocene although environments remained largely open areas of herb-rich grassland and juniper scrub. Willow was probably present locally and *Pinus* appears to have been significant at Aros Moss, although it should be noted that neither this or the Racks Moss profile is radiocarbon-dated and the *Pinus* pollen may be of Lateglacial date. In the Inner Hebridean pollen diagrams for the early Holocene, *Pinus* is recorded only in very low amounts compared to its early presence in Lateglacial-Holocene transitional profiles on Mull and Skye (Birks, 1983; Lowe and Walker, 1992a, 1992b; Walker and Lowe, 1985, 1986a, 1986b, 1987).

Other pollen profiles from the Solway Firth (Moar, 1969), Dubh Lochan, Loch Lomond (Stewart *et al.*, 1984), Pulpit Hill, Oban (Tipping, 1992) and Loch Maree, Loch Assynt and Sionascaig (Birks, 1980) amongst others (refer to Figure 7.1) confirm the general picture presented above for early Holocene vegetation assemblages, although local variations in amounts of willow scrub, *Empetrum* heath and tall-herbs occur. Following the expansion of *Corylus*, the Scottish mainland percentage profiles suggest that *Corylus* populations were not as dense with increasing latitude, or at least that flowering of this taxon was suppressed due to less favourable climatic conditions. The percentage *Corylus* curves at Loch Maree, Loch Assynt and An Druim only reaches between 20-30 % TLP (Birks, 1980). In other northerly pollen profiles, such as Loch Clair, Loch Assynt and An Druim *Betula* pollen reaches high percentages (c. 50 % TLP) (Birks, 1980), which also reflects the cold and wet climate of northwest Scotland.

The early Holocene flora of the Outer Hebrides is represented in a number of pollen diagrams from various locations in the islands (Figure 7.1) which indicate local variations in the extent of birch woodland, *Empetrum* heath, juniper scrub and grassland similar to those elsewhere in the Inner Hebrides and the western mainland. Although *Corylus* is present in most of the Outer Hebridean pollen records from c. 9000 BP (8225 cal. BC), neither hazel nor birch appear to attain levels achieved in the more sheltered Inner Hebrides or in the south and west coast mainland, as percentages and concentrations of these taxa are comparatively low (e.g. Birks and Madsden, 1979; Bennett *et al.*, 1990; Fossitt, 1996).

7.2.2 The *Corylus* rise (from c. 9800 BP [9300 cal. BC])

The early postglacial behaviour of *Corylus avellana* and its representation in pollen profiles has been the subject of much debate (Smith, 1970; Boyd and Dickson, 1986; Huntley, 1993; Edwards and Berridge, 1994; Edwards, in press; Sugden and Edwards, in press). Isopollen maps (Huntley and Birks, 1983) and pollen isochrones (Birks, 1989; Whittington and Edwards, 1997) indicate that *Corylus* was established in western Scotland and the Inner and Outer Hebrides by c. 9500 BP (8900 cal. BC). In pollen diagrams from the Outer Hebrides, *Corylus* never reaches the high percentage values seen in profiles from the Inner Hebrides and western Scotland (as much as 80 % TLP at Loch a'Bhogaidh, this volume) where rapid increases to these high values may occur. The reason for these rapid expansions is not entirely clear, and it is assumed that climate, migrational lag of other taxa, local ecology, soils and hydrology may all have influenced *Corylus* to different degrees (Huntley and Birks, 1983; Boyd and Boyd, 1986; Huntley, 1993). Human assistance has also been cited as possibly assisting the rapid expansion of this taxon (Smith, 1970; Huntley and Birks, 1983; also cf. Edwards, 1990; Huntley, 1993).

An assessment of the different timings of the *Corylus* rise in western Scotland and its islands, and the different conditions associated with this may divulge further informations on the possible causes of the early Holocene behaviour of *Corylus*. The range of dates for the hazel rise at selected sites from the Inner Hebrides and some from the west coast of Scotland is presented in Figure 7.2. The low *Corylus* values in many Outer Hebridean pollen profiles mean that the *Corylus* rise is not as pronounced and dates for its rise in these islands have been excluded. The hazel rise or expansion is defined *sensu* Smith and Pilcher (1973) as the point where the taxon begins a climb to sustained high percentages in the pollen profiles. The dates for the hazel expansions denoted in Fig. 7.2 are spread over c. 2500 radiocarbon years. The earliest expansions of hazel occur at Loch an t'Suidhe and Loch Cholla in the Inner Hebrides c. 9800 BP (8900 cal. BC) and most of the expansions occur before c. 9000 BP (8225 cal. BC). These include a range of sites from the southern Inner Hebrides to the north of Skye. Dates for the spread of *Corylus* at A'Chrannag, Ulva and Glen More, Mull (Walker and Lowe, 1985) are later, c. 9000 - 8500 BP (8225 - 7470 cal. BC), and later dates are recorded for Glen Varrigill and Loch Fada on Skye (Birks and Williams, 1983;Walker and Lowe, 1991a) as well as Loch Clair on the west coast mainland (Birks, 1980).

The apparent rapidity of the *Corylus* expansion at some sites may be the result of sub-optimal sample quality. The *Corylus* rise at An Druim in northwest Scotland dates to c. 10,000 BP (9530 cal. BC) and also corresponds with a rapid increase in *Betula* (Birks, 1980). The dates on the profiles indicate extremely rapid sedimentation in the early Holocene and as sampling resolution is low it is difficult to determine the chronology of events from this profile.

Pollen influx may be preferable in assessing the early Holocene *Corylus* expansion. At Loch a'Bhogaidh there are differences in the percentage representations of the *Corylus* rise in the various profiles from the site, but *Corylus* influx is high in all the profiles. In contrast, *Corylus* influx is low at Loch an t'Suidhe despite this taxon rising rapidly to high percentage values c. 9800 BP (9300 cal. BC). The influx curves suggest that the *Corylus* woodland was denser and established more quickly at Loch a'Bhogaidh than at Loch an t'Suidhe, although the percentage curves would suggest otherwise.

There are no indications that latitudinal differences affected the spread of early *Corylus* populations although flowering or the extent of *Corylus* populations may have been limited with northerly latitude and with a greater degree of exposure to westerly winds and rain. In northwest Scotland the date of the *Corylus* rise is comparable with that of the Inner Hebrides islands but percentages remain lower (c. 20-30 % TLP) than in Inner Hebrides and southwest coast profiles (c. 50 %).

Altitude is not likely to have affected the *Corylus* expansion and its rate of spread at the sites in question (cf, Birks, 1973). Site position may have influenced the *Corylus* expansion in different localities. Many of the sites where this occurs prior to c. 9000 BP (8225 cal. BC) are coastal (e.g. Loch an t'Suidhe, Mull) or in areas of subdued topography (e.g. Loch a'Bhogiadh, Rhinns of Islay; Loch Cholla, Colonsay). In contrast, Coire Claccach and Torness in the Glen More region of Mull and Loch Fada on Skye are surrounded by steep, high slopes and are situated in the interior of the islands. Glen Varrigill on Skye is also situated inland. The physical barrier of topography combined with the inland positions of these sites could have delayed the expansion of *Corylus* to these areas, and low percentage values of this taxon in the earlier sections of the pollen profiles could result from pollen derived from the wider region. Expanses of water with strong currents separating the islands from the mainland have also been suggested as delaying the expansion of *Corylus* on Arran (Boyd and Boyd, 1986) and this was possibly the case on Ulva, where *Corylus* at A'Chrannag does not expand until c. 8700 BP (7790 cal. BC).

7.2.2.1 The influence of soils

Soils may also have imposed limitiations on early Holocene *Corylus* populations. The spread of *Corylus* may have been affected by the distribution of acidic and thin soils, as this taxon prefers base-rich soils. However, *Corylus* occurs relatively early in the Outer Hebrides and northwest

Scotland where high levels of precipitation may have hindered soil development and caused early acidification and leaching. In addition to climate, other influences on soils may have contributed to the uneven expansion of *Corylus* in the early Holocene. Glenn Varrigill and Loch Fada on Skye, and the Glen More region of Mull, where *Corylus* expands late, are in areas known to have been glaciated in the Loch Lomond Readvance (Lowe and Walker, 1986a; Walker and Lowe, 1990; Ballantyne and Dawson, 1997). Huntley (1993) suggests that soil development could have been initiated in the Allerød interstadial, but in areas subjected to subsequent glacial advance and periglacial activity, pedogenic development would have been impeded until the early Holocene. The extremes of topography near these pollen sites would also have hindered soil stability following deglaciation and the development of soils able to support *Corylus* woodlands could have been delayed.

It is unlikely that the effects of glaciation during the Loch Lomond Stadial and the extremes of slope could have delayed the *Corylus* expansion at A'Chrannag and Livingstone's Cave basins on Ulva. The southern coastline of the island contains many sheltered valleys with no extremes of topography and it is located close to the western coastline of Mull where at Loch an t'Suidhe, to the south-west of Ulva, the *Corylus* expansion occurs c. 9800 BP (9300 cal. BC). Therefore, notwithstanding difficulties arising from possible hiatuses, or the unreliability of the chronology, other factors are probably responsible for the later expansion of *Corylus* in southeast Ulva. The absence of *Corylus* in the early section of the AC1 profile does not exclude the possibility that the spread of *Corylus* occurred earlier elsewhere on the island, and given the earlier *Corylus* rise at many sites elsewhere in the Inner and Outer Hebrides, hazel was probably present on Ulva much earlier than is currently recorded.

7.2.2.2 Human influence and the *Corylus* expansion.

The contribution of human influence on the *Corylus* rise has been largely discounted (cf. Edwards, 1990; Huntley, 1993) and at nearly all the sites included in this study there is no evidence to suggest that people may have influenced the early Holocene *Corylus* expansion. However, at A'Chrannag on Ulva there are increases in microscopic charcoal associated with the *Corylus* rise, and *Calluna vulgaris* increases simultaneously, suggesting probable local burning. Although the expansion of *Calluna* heath may be coincidental, and fires (whether of natural or human origins) may have been confined to areas of heathland, there remains a possibility that burning on Ulva may have assisted the spread of *Corylus avellana*, and that this may have been a result of the use of fire by Mesolithic people

7.2.2.3 Summary of the evidence surrounding the *Corylus* rise

The above suggests that the spread and expansion of *Corylus* in the Inner Hebrides, Outer Hebrides and western Scotland is not as straightforward as pollen isochrone maps might indicate. Low sampling intervals and the interpretation of poorly dated percentage data may have provided erroneous information in the past. Variations in topography, soils and antecedent site conditions could all have influenced the spread and behaviour of the taxon. Climate and latitude may have also affected the post-colonization behaviour of *Corylus* but there is little evidence in the currently available pollen data to support this. From the available pollen data it is not possible to draw any firm conclusions about the factors responsible for the spread and expansion of *Corylus* in the Inner Hebrides and Scotland. Further data is obviously required, and should not be restricted to pollen analysis but should incorporate wider palaeoenvironmental investigation (Section 8.3).

7.3 Holocene vegetation patterns c. 9000 - 5000 BP (8225 - 3870 cal. BC)

Between c. 9000 and 8000 BP (8225 - 3870 cal. BC) *Ulmus* and *Quercus* expand in most profiles from the Inner Hebrides, Outer Isles and western Scotland, indicating a diversification of woodland which fits the general scheme for the spread of these taxa in isopollen maps (Huntley and Birks, 1983), and isochrone maps (Birks, 1989; Whittington and Edwards, 1997). The variations in the timings of the expansions of these taxa at specific sites may be explained by differences in local topography, soils, competition and the accessibility of a site to taxon propagules.

Comparatively late expansions of *Ulmus* and *Quercus* at Coire Clacchach in the Glen More region of Mull, dating to c. 7800 BP (6640 cal. BC) and 7000 BP (6010 cal. BC) respectively, provide an example of the potential of environmental factors as influences on the abundance of these taxa. Although a limiting factor to the spread of these taxa may have been the delayed transport of propagules into this mountainous region, these taxa expanded earlier at Torness, also in the Glen More region, c. 8200 BP (7280 cal. BC) (Walker and Lowe, 1985). However, Torness in more sheltered and the authors suggest that site exposure could have been a factor limiting the success of *Quercus* and *Ulmus* at Coire Clachach. Similar environmental constraints may have operated at Beinn Reudle in north-west Mull. The undated pollen profile from this site contains very little *Ulmus* and *Quercus* pollen (similar in percentages to those recorded in the Outer Hebrides) and Beinn Reudle is exposed to salt-laden westerly winds and rain. This has resulted in the leaching, acidification and thinning of soils (Lowe and Walker, 1986). At Loch an t'Suidhe on the exposed Ross of Mull peninsula, *Ulmus* and *Quercus* influx is very low until c. 7800 BP (6640 cal. BC) suggesting a delay in the colonisation of the site by these taxa. Kinloch, Rum and Loch

Cholla, Colonsay also provide examples of exposed sites where *Ulmus* and *Quercus* are poorly represented in the pollen profiles and may never have been locally present.

A substantial increase in *Ulmus* and *Quercus* occurs in the Loch an t'Suidhe profiles c. 5700 BP (4530 cal. BC) and this corresponds with the late expansion of these taxa at A'Chrannag, Ulva. Reasons given in Chapter 5 for the delayed expansion of *Ulmus* and *Quercus* at the site were the persistence of a fire climax community of *Corylus* and *Calluna*, possibly resulting from human interference, or the difficulty of propagules reaching the site due to the island being surrounded by cliffs and fast flowing water. However, increased arboreal pollen influx at Loch an t'Suidhe, although possibly coincidental, may also be linked to the late arboreal expansions of these taxa on Ulva. Although all arboreal pollen influx rates increase slightly in the 2LS profile c. 5700 BP (4530 cal. BC), it is *Ulmus* and *Quercus* which show the greatest increases. As sea levels were higher in the early Holocene reaching a maximum between c. 8000 and 6000 BP (6860 and 4910 cal. BC), falls in local sea level may have resulted in less salt spray at the sites, to which *Quercus* and *Ulmus* could be particularly sensitive. This may then have allowed these taxa to increase as components of woodland in western Mull and on Ulva. Earlier high sea levels may have infiltrated the water table at coastal sites, and subsequent falls would have produced lower ground water salinity which may also have encouraged the spread of *Quercus* and *Ulmus* at coastal sites.

It was also mentioned in Chapter 5 that the dates for the woodland expansion on Ulva may be erroneous and an earlier expansion, possibly c. 7700 BP (6600 cal. BC) is possible. This would correlate with expansions of *Quercus* and *Ulmus* in remote or exposed regions of Mull (above). A period of climatic cooling (Alley *et al.*, 1997; Barber *et al.*, 1999; Willemse and Törnqvist, 1999) has been identified as occurring from c. 7700 BP (6600 cal. BC) which may have adversely affected woodland at Loch a'Bhogaidh and Loch an t'Suidhe (this volume), where human interference in vegetation may also have occurred. Given that in some areas mixed deciduous woodland may have increased in some areas despite a colder, drier climate, this reinforces the suggestion that at Loch a'Bhogaidh and Loch an t'Suidhe, human impact may have been more important than climatic conditions in producing changes in local vegetation.

The later expansions of *Ulmus* and *Quercus* suggested by pollen diagrams from the north-west mainland of Scotland (e.g. Loch Assynt, An Druim, c. 7000 BP [6010 cal. BC] both Birks, 1983), are probably connected to a slower rate of spread due to climatic constraints (Birks, 1989). The limitations imposed by climate on both these taxa mean that they only appear in low amounts in most pollen diagrams from the Outer Hebrides from c. 8000 BP (6860 cal. BC) (e.g. Loch Lang, S. Uist, Bennett *et al.*, 1990; Loch Phuinnd, S.Uist, Fossitt, 1996; Borve, Benbecula, Edwards and Whittington, 1997; Callanish, Lewis, Bohncke, 1986. The low frequencies suggest that elm and oak were minor components of woodland in the Outer Hebrides rather than the result of long distance transport of pollen grains as suggested by Birks and Madsden (1979), but they were probably restricted to sheltered valleys and better soils, allowing birch-hazel woods to dominate over the greater parts of the islands.

Mixed woodland persisted in most places in the west coast of Scotland and the Inner Hebrides throughout the later Holocene. The activities of Neolithic people began to increase openings in woodland from c. 5000 BP (3810 cal. BC) (e.g. Loch a'Bhogaidh, Islay, Edwards and Berridge, 1994; Kinloch, Rum, Hirons and Edwards, 1990; Machrie Moor, Arran, Robinson and Dickson, 1988). Increased oceanicity of climate may also have assisted the spread of heathland and bog over many areas, but at some sites woodland persisted until very recently (c.f. Walker and Lowe, 1985).

In contrast to the above, the birch-woodland cover of the Outer Hebrides declined comparatively early. From c. 6200 BP (5130 cal. BC) *Calluna* heath and grassland increase at the expense of trees in many pollen diagrams (e.g. Borve, Benbecula, Whittington and Edwards, 1997), and indicators of disturbed ground such as *Plantago lanceolata* and *Potentilla*-type appear (Bennett *et al.*, 1990; Fossitt, 1996). In some instances these changes in vegetation may be attributed to Mesolithic activity (see below), but the exposed nature of many partsof the Outer Hebrides would provide fairly marginal conditions for woodland and high levels of rainfall, disturbance by storms from the Atlantic, and cold winds could easily reduce woodland and allow blanket mire and heath development.

In the more northerly parts of the western mainland, expansions in *Pinus* occur in some pollen profiles from c. 7000 BP (6010 cal. BC) as *Betula* and *Corylus* decline. Examples include Loch Maree, Sionascaig and Loch Clair, where *Pinus* dominates the pollen profiles until c. 4400 BP (3120 cal. BC) (Birks, 1980). Relatively early reductions in *Ulmus* c. 5500 BP (4380 cal. BC) in some profiles from the Scottish mainland indicate that climate and exposure may have strongly influenced vegetation patterns here, and the later reductions in *Pinus* are probably also linked to increased rainfall. However, the influences on vegetation patterns may be more complicated than currently available pollen profiles and radiocarbon dates suggest.

7.3.1 *Alnus* expansion

The postglacial pattern of spread for *Alnus glutinosa* is complicated and it is largely acknowledged that site-specific factors influenced the expansion of alder rather than climatic amelioration (Birks, 1989; Chambers and Elliott, 1989; Bennett and Birks, 1990; Tallantire, 1992). Birks's (1989) pollen isochrones follow a trend indicating that *Alnus* was present in substantial amounts in western Scotland and the Inner Hebrides by c. 6500 BP (5460 cal. BC). *Alnus* was probably present in the Outer Hebrides from this time. *Alnus* is recorded as macrofossil wood from Lewis and Harris (Fossitt, 1996), and it is present in most pollen profiles from the Outer Hebrides in minor amounts (Birks and Madsden, 1979; Bohncke, 1988; Bennett *et al.*, 1990; Fossitt, 1996; Whittington and Edwards, 1997). Nevertheless, it appears to have been only a minor component of woodland and was possibly more widespread on South Uist (at Loch Lang, Bennett *et al.*(1990) and Loch Phuinnd, Fossitt (1996)) from c. 6000 BP (4910 cal. BC) than elsewhere in the Outer Isles. These sites are situated on the east of the island and are relatively sheltered from prevailing westerly winds. Many parts of the Outer Hebrides do not have pollen records and *Alnus* may have had a more widespread distribution than is currently recognised.

At some sites in the Inner Hebrides, *Alnus* expands earlier than pollen isochrones suggest. The early expansion of *Alnus* occurs c. 8000 BP (6860 cal. BC) at Drimnagall in the north of the Kintyre Peninsula (Rymer, 1984), at Rhoin Farm also on the Kintyre Peninsula at 6910±90 BP (5830 cal. BC) (Edwards, 1990) and at Moine Mhor, near Oban, c. 7000 BP (6010 cal. BC) (Haggart and Sutherland, 1992). At Loch an t'Suidhe, western Mull, *Alnus* expands c. 6800 BP (5720 cal. BC). Alder is recorded as pollen and macrofossils in archaeological contexts from the Farm Fields site at Kinloch on Rum from c. 7900 BP (6770 cal. BC) indicating an early local presence

(Hirons and Edwards in Wickham-Jones, 1990), although its expansion in the Kinloch monolith profiles is not until 6430±90 BP (Edwards and Hirons, 1990).

The Inner Hebridean sites referred to above are all located in fairly coastal positions and may have experienced a degree of groundwater salinity and waterlogging early in the Holocene. *Alnus* is able to tolerate saline conditions (Chambers and Elliott, 1989) and high levels of salinity could have restricted the growth of other arboreal taxa at the same sites with *Alnus* emerging as the successful competitor.

Associations between the expansion of *Alnus* and human activity have been inferred for some sites including Kinloch and Rhoin Farm (Edwards, 1990) where increases in microscopic charcoal occur at the main *Alnus* rise. McVean (1956a, 1956b) associated the spread of *Alnus glutinosa* with clearance of other vegetation by burning, which may also have increased runoff and nutrient inputs to low-lying areas (Moore, 1986). Although there is no increase in charcoal at the *Alnus* rise at Loch an t'Suidhe, the expansion of *Alnus* occurs shortly after a phase of woodland reduction linked to possible anthropogenic activity, and high levels of charcoal and increases in *Calluna* may indicate that areas of the catchment were burned. This may have led to increased waterlogging and peat formation in the valley floor (Chapter 4) thus assisting the spread of *Alnus*. Increases in *Alnus* in the central LABI and LABVII profiles at Loch a'Bhogaidh also occur after a prolonged period of inferred anthropogenically-induced woodland reduction and coincide with indications of peat formation at the loch edges.

In contrast to the above, there are strong indications of burning in the A'Chrannag profiles from Ulva, but the *Alnus* expansion is dated to c. 5700

BP (4530 cal. BC), although the date may not be correct. Following its expansion, pollen influx values indicate that alder had a strong local distribution. It appears to have populated the potentially wetter and more sheltered areas of A'Chrannag bog, and in the drier parts of the bog to the north, birch became predominant. The Livingstone's Cave profiles indicate that alder was present in substantial amounts in the basin itself, which was probably subjected to extremes of waterlogging according to the preceding . stratigraphy and pollen assemblages. This suggests that *Alnus* may also be strongly influenced by local hydrological conditions and by competition from existing vegetation. Although anthropogenic influences can occasionally result in conditions favourable to the expansion of *Alnus*, the possible links at most sites remain enigmatic, and where these are suggested, an interpretation of natural vegetation succession due to changing hydrology and ecological dynamics may be equally as valid.

7.4 The distribution of human activity as suggested in pollen diagrams

Detailed Holocene vegetation histories from the west and northwest coastal areas of Scotland are few and those published lack resolution, microscopic charcoal counts and radio-carbon dates. Fluctuations in the *Corylus* and *Betula* curves of a diagram from Aros Moss, Kintyre could result from Mesolithic activity, but more convincing evidence of human impact occurs in the later parts of the profile and suggests Neolithic clearance and cereal cultivation (Nichols, 1967). Unfortunately there are no dates attached to the profile to confirm these hypotheses. Early cereal-type pollen is recorded from pre-elm decline deposits from Rhoin Farm, Aros Moss, Kintyre (5640±80 BP [4480 cal. BC], Edwards and McIntosh, 1988) and from Gallanach Beg, southwest Oban (undated, Rhodes *et al.*, 1992) which could indicate pioneer cultivation (Edwards and McIntosh, 1988; MacDonald and Edwards, 1991). Fluctuations in the early Holocene *Calluna* profile from An Druim, Sutherland (Birks, 1980) may reflect Mesolithic influences on heathland, but there is no charcoal record from the site, and in any case, natural cycles linked to exposure and climate of high latitudes may have influenced expansions in *Calluna* heath. Other than the above, there are no published pollen records from the west coast of Scotland which indicate human activity, although this is probably due to the lack of high resolution and radiocarbon dated investigation rather than an absence of people. Pollen profiles from near coastal sites such as Loch Sionascaig and Loch Clair contain increasing amounts of *Calluna vulgaris, Plantago lanceolata, Potentilla* and other herbs from as early as c. 9000 BP (8190 cal. BC) (Birks, 1980) probably as a result of their exposed locations. The removal of woodland by people could also result in increases in these taxa, but human impact will remain undetected as a result of this equifinality.

In contrast, there are many indications of human activity in the Inner Hebridean pollen records, although some episodes of woodland reduction which may once have been interpreted as human impacts may have been largely influenced by climatic changes. Mesolithic activity may nevertheless have exacerbated woodland reduction and erosion during this period of climatic cooling, particularly given the antecedent evidence for possible Mesolithic impacts and the archaeological evidence for Mesolithic occupation at some sites. Mesolithic and later Neolithic impacts could appear in all the pollen diagrams from this study and are inferred as ranging from small scale clearances in woodland to reductions of woodland over a wide area where burning to create *Calluna* heath and grassland may have occurred. Cereal cultivation may have taken place on Ulva from c. 4600 BP (3540 cal. BC) and on Rum from c. 3950 BP (2440 cal. BC). Cereal pollen appears in the LABI profile from Loch a'Bhogaidh shortly after c. 3500 BP (1880 cal. BC). Other pollen records from Arran (Robinson and Dickson, 1988; Edwards and

McIntosh, 1988), Colonsay (Andrews *et al.*, 1987) and Newton, Islay (McCullagh, 1991) display evidence of human activity and there are indications of similar events in pollen records from the Outer Hebrides (e.g. Loch an t'Sil, Edwards, 1997a; , Callanish, Bohncke, 1988).

Figure 7.3 summarizes the indications of human impact for the Holocene to c. 3500 BP (1880 cal. BC) at sites from the Inner and Outer Hebrides. For convenience the transition from the Mesolithic to the Neolithic is placed at c. 5000 BP (3810 cal. BC) but it is acknowledged that the cultural change was probably diffuse and may have been initiated earlier or later than this in different areas.

7.4.1 The Mesolithic

It is evident that most of the evidence for Mesolithic activity appears in the Inner Hebrides, notably at Loch a'Bhogaidh, Loch an t'Suidhe, Loch Cholla, A'Chrannag and Kinloch. The earliest possible impacts are recorded at Loch a'Bhogaidh from c. 8500 BP (7540 cal. BC) and take the form of small reductions in birch-hazel woodland, although the lack of microscopic charcoal in the profiles suggests that at least some of these could be of natural origin. A much longer phase of woodland reduction occurs at Loch a'Bhogaidh from c. 7700 - 7000 BP (6600 - 5780 cal. BC). Although this is probably a reflection of a colder, dry period, there is an indication that Mesolithic activity may also have influenced vegetation changes at the site, particularly from c. 7300 BP (5910 cal. BC). A phase of woodland reduction of similar antiquity and probably of similar origins, occurs at Loch an t'Suidhe, although in addition to increases of Poaceae and Cyperaceae at the expense of birch-hazel woodland, *Calluna vulgaris* also increases, possibly arising from fires set by Mesolithic people as indicated by increased Ch:P and charcoal influx. At Loch Cholla, a reduction in birch-hazel woodland is of longer duration (c. 7500 - 6000 BP [6320 - 4910 cal. BC]) than at Loch a'Bhogaidh and Loch an t'Suidhe, but this may be due to the large spacing of radiocarbon dates on the core leaving changes in sedimentation and possible hiatuses undetected. The stratigraphy of the Loch Cholla profile for this period is silty peat, rather than gyttja, and impact here may have been more localised than at Loch a'Bhogaidh and Loch an t'Suidhe (both lakes), and may therefore have registered in the pollen record for a longer period.

The increases in *Calluna vulgaris* in the Loch an t'Suidhe and Loch Cholla profiles may be the result of different vegetation succession or the proximity of activity to the core sites. *Calluna vulgaris* pollen does not travel far, and from c. 7700 - c. 7300 BP (6190 - 5780 cal. BC) at Loch a'Bhogaidh, human activity may have been some distance from the loch edge, thus *Calluna* increases may remain undetected. However, the comparative lack of microscopic charcoal in the Loch a'Bhogaidh profiles suggests that the direct burning of vegetation did not occur extensively there. Charcoal increases in the later profiles from c. 7300 - 7000 BP (6190 - 5780 cal. BC) may result from local camp fires, and proximity of these to the loch edge. In contrast, burning appears to have been sustained at Loch an t'Suidhe and was possibly widespread in order to produce increases in *Calluna*. By implication, burning of vegetation may also have taken place at Loch Cholla and similar practices may have taken place at A'Chrannag on Ulva, as high levels of charcoal from c. 8500 BP (7540 cal. BC) correspond with increases in *Calluna* and grasses. Burning may also have maintained an abundance of *Corylus* pollen in the Ulva profiles by effectively coppicing hazel (cf. Edwards, 1990) and reducing the spread of other arboreal taxa. High levels of charcoal and *Calluna* at the base of the Machrie Moor profile c. 8700 BP (7790 cal. BC) may also have resulted from similar Mesolithic activity (Robinson and Dickson, 1988).

In the Outer Hebrides there is comparatively little evidence of potential Mesolithic impacts, particularly on the scale seen in the Inner Hebridean profiles. Two relatively short periods of woodland reduction occur at Loch an t'Sil, South Uist, c. 8000 BP (6910 cal. BC) and 7800 BP (6640 cal. BC), lasting c. 150 years and 70 radiocarbon years respectively. Both of these indicate that localised burning produced increases in grasses, herbs and *Calluna* (Edwards *et al.*, 1995; Edwards, 1996). Increases in herb-rich grassland and *Calluna* heath occur at Reineval, South Uist, and these appear to be linked to increases in microscopic charcoal. This could be evidence of human activity, but lightning strikes would produce the same effects, and the open environment and exposure to westerly rainstorms could have reduced tree cover and increased bog and heathland growth. A decline of woodland and the development of heath and machair grassland occurs at Borve on Benbecula c. 6200 BP (5130 cal. BC), and increases in microscopic charcoal and *Pteridium* at this transition led Whittington and Edwards (1997) to suggest that Mesolithic people may have been responsible, at least in part, for this transition

Only Callanish, Lewis provides any firm indication of substantial Mesolithic activity in the Outer Hebrides. Here fluctuations in the birch-hazel woodland are matched by increases in charcoal, grasses, herbs and *Calluna*. Dates indicate that this may have started c. 8300 BP (7330 cal. BC) and although intermittent, this disruption of woodland at Callanish continues through the Mesolithic to the early Neolithic at c. 4500 BP (3140 cal. BC).

It is possible that little evidence for Mesolithic impacts is recorded in the Outer Hebridean profiles due to the lesser amounts of woodland for many sites in the islands compared to those of the Inner Hebrides, and the potential for natural disturbances in an exposed and fragile ecosystem. Indeed, the pollen indicates that in many areas of the Outer Hebrides, birch-hazel woods declined from c. 6000 BP (4910 cal. BC) followed by the development of blanket bog and *Calluna* heath over many areas (Birks and Madsden, 1979; Bennett *et al.*, 1990; Edwards *et al.*, 1995; Fossitt, 1996; Whittington and Edwards, 1997).

If all the disturbances in the pollen diagrams referred to above and in Figure 7.4 are the result of human impact, then the evidence points to the widespread use of fire during the Mesolithic to initiate vegetation changes. It is arguable as to whether or not this use was intentional, particularly in cases where woodland reduction and recovery occurs in a short space of time. It is not unlikely that the regeneration of trees following a single fire may take 70 - 100 years, such as is indicated at Loch an t'Sìl, particularly in a marginal environment where pressure from grazing animals may take its toll. Charcoal may also derive from the secondary burning of felled trees and may or may not be natural. However, it may be argued that sustained burning over a period of c. 800 years as is indicated at Loch an t'Suidhe, if of anthropogenic origin, is unlikely to result accidentally. Microscopic charcoal records on Ulva also indicate that fires occurred over lengthy periods of time. Thus there is every indication that Mesolithic people in the Inner and Outer Hebrides could have intentionally used fire as a means of modifying their environments, possibly to create grazing for game, increase fowl, and perhaps to increase areas of berries and rhizomous plants for consumption.

7.4.2 The Neolithic

At many of the sites which bear evidence of Mesolithic impacts, there are indications that vegetation disturbances continued through the Neolithic. At A'Chrannag on Ulva it appears that similar cycles of burning linked to the propagation of *Calluna* heath continued until at least c. 4200 BP (2790 cal. BC), but there is additional evidence in this and other profiles on Ulva that woodland clearance and cereal cultivation occurred from as early as c. 4400 BP (3120 cal. BC). Intermittent reductions in trees combined with increases in grasses, and herbs such as *Potentilla* and *Plantago lanceolata* continue to the top of the sampled profiles AC2, LC1 and LC2.

The extensive opening of woodland at Kinloch, Rum occurs from c. 3950 BP (2440 cal. BC) and appears to have been at least partially caused by human activity, particularly as cereal pollen and increases in *Plantago lanceolata* and Brassicaceae amongst other herbs, are detected in the four profiles from the site. LABI at Loch a'Bhogiadh shows cereal-type pollen and the opening of woodland from c. 3590 BP (2440 cal. BC).

In the Outer Hebrides, indicators of open environments such as grasses and herbs, including *Plantago lanceolata*, increase from c. 4000 BP (2530 cal. BC) (Birks and Madsden, 1989; Newell, 1988; Bennett *et al.*, 1990; Fossitt, 1996) which could suggest widespread grazing of domestic animals and increased land use pressures. However, increased oceanicity in the Atlantic from c. 4000 BP (2530 cal. BC) (Hirons and Edwards, 1990) may also have played a part in changing vegetation.. Nevertheless, the presence of Neolithic people in the Outer Hebrides is confirmed by numerous archaeological finds (cf. Newell, 1988) and stone monuments, particularly the Callanish stone circle (Henshall, 1973). A core closeby provided indications of a considerable period of Mesolithic impacts and evidence for human activity in the profile resumes c. 4000 BP (2530 cal. BC). This includes increases in microscopic charcoal, herbs *including Plantago lanceolata, Trifolium* and Brassicaceae, and cereal-type pollen (Bohncke, 1986). This, and evidence from elsewhere, seems to confirm that Neolithic farming took place in the Outer Isles (Barclay, 1997; Mulder, 1999).

7.5 The *Ulmus* decline

There are few pollen profiles from the Inner Hebrides and west coast of Scotland which document the *Ulmus* decline in detail. Reliably dated pollen profiles featuring the *Ulmus* decline are from Moorlands, Machrie Moor, Arran (Robinson and Dickson, 1988; Edwards and McIntosh, 1988) and Rhoin Farm, Aros Moss, Kintyre Peninsula (Edwards and McIntosh, 1988). Securely dated *Ulmus* profiles for the Inner Hebrides are limited to the sites discussed in earlier chapters and listed in Table 7.2, where AMS dates apply directly to *Ulmus* decline levels, or interpolated dates can be applied. Sites from Skye with interpolated dates for Ulmus declines are Loch Meodal, Loch Cleat and Loch Ashik (Birks and Williams, 1983). There are no *Ulmus* declines in profiles from Kinloch, Rum (Hirons and Edwards, 1990) or Loch Cholla, Colonsay (Andrews *et al.*, 1987) where *Ulmus* pollen is recorded in very low quantities and this is also the case for the Outer Hebrides.

Table 7.2 lists the *Ulmus* declines and Figure 7.4 shows the spread of dates for these. Error bars are at a range of 2 and 1 Standard Deviations in respective graphs where actual dates are available.

Although a range of dates may occur due to the statistical errors inherent in the dating of pollen profiles and the lack of accuracy in defining the actual point of decline in the pollen diagram (cf. Hirons and Edwards, 1986), there is nevertheless more than one phase of *Ulmus* decline with multiple declines occurring in some profiles. Multiple or single later *Ulmus* declines are not limited to the Inner Hebrides (Ulva, Arran, Islay) and occur in pollen diagrams from northeast Ireland (Hirons and Edwards, 1986), Wales (Smith and Cloutman, 1988) and Fife, eastern Scotland (Whittington *et al.*, 1991) amongst others. All of these are multiple profile studies which bolsters the reality of the phenomenon.

There are various hypothesized causes for the decline of *Ulmus* pollen in Britain and Ireland. These incorporate climate change, erosion and soil deterioration, pathogenic attack and human impact (e.g. Pilcher *et al.*, 1972; Garbett, 1981; Groenman-van Waateringe, 1983; Girling and Greig, 1985; Hirons and Edwards, 1986; Peglar and Birks, 1993; Digerfeldt, 1997). It is largely acknowledged that a combination of factors could be reponsible for these declines and that different factors may operate at different sites.

7.5.1 Climatic influences and the *Ulmus* decline

Climate change characterised by increased rainfall in the British Isles at c. 5000 BP (3810 cal. BC) is frequently cited as a reason for the classic elm decline. However, in Scotland and Ireland a *Pinus* decline initiated in some areas as early as c. 4800 BP (3570 cal. BC) and peaking c. 4200 - 3800 BP (2740 - 2250 cal. BC) has been attributed to increased rainfall and substrate waterlogging (Bennett, 1984; Dubois and Ferguson; 1985; O'Connell *et al.*, 1986; Whittington and Edwards, 1997; Willis *et al.*, 1997). There are simultaneous reductions in *Pinus* and *Ulmus* c. 4800 BP (3570 cal. BC) recorded in published pollen diagrams from northeast Ireland (Hirons and Edwards, 1986), Black Loch, Fife (Whittington *et al.*, 1991) and Machrie Moor, Arran (Robinson and Dickson, 1988) and in the A'Chrannag and Livingstone's Cave profiles in this study. As both taxa could have responded to the same environmental stresses, it is extremely plausible that climate change had an adverse effect on *Ulmus* populations. However, the recovery of *Ulmus* in some profiles and the variable timings of the *Ulmus* declines indicate that the effects of climate were not immediate or direct. Factors such as local differences in soils, exposure, ecological competition, disease and human impact may have moderated or exacerbated climatic effects. In some instances *Ulmus* persists until until much later (e.g. 3590±100 BP [1940 cal. BC] at Loch a'Bhogaidh; 3600 BP [1940 cal. BC] at LC1, Livingstone's Cave). *Pinus* has also been known to survive into the historic period in lowland and sheltered locations of northern Ireland (Bradshaw and Browne, 1987). This suggests that in some instances, site-specific factors may outweigh climatic influences on some taxa (cf Smith and Cloutman, 1988; Whittington *et al.*, 1991; Edwards and Berridge, 1994).

7.5.2 Soils and site location

The effects of soils and site location were mentioned earlier in connection with the initial expansion of *Ulmus*. It is not surprising therefore that the earliest permanent reductions of *Ulmus* occur at exposed locations such as A'Chrannag and Loch an t'Suidhe (refer to Fig. 7.4; Table 7.2). Soils here may have become eroded and leached relatively early due to exposure to Atlantic storms and peat formation occurred early in the Holocene from c. 8500 BP (7470 cal. BC) at A'Chrannag on Ulva, and c. 6800 BP (5700 cal. BC) at Loch an t'Suidhe. A recovery in *Ulmus* demonstrated by multiple declines at some sites including those from Livingstone's Cave basin, Ulva, suggests that the initial declines of this taxon could be the result of episodes of disease or reduced flowering brought about by environmental stresses. Most of the sites where *Ulmus* recovers from early declines or where a single decline occurs later than c. 5000 - 4700 BP (3810 - 3460 cal. BC) are sheltered or positioned inland where topography is not extreme. These factors may mean that soils there were less prone to waterlogging, leaching and erosion, thus allowing *Ulmus* to recover from the initial impacts of climatic deterioration.

7.5.3 Human impact and the *Ulmus* declines

Indications of human activity including cereal-type pollen and increases in herbs and microscopic charcoal coincide with or directly preceed the *Ulmus* decline at some sites in Scotland and northern Ireland (e.g. Pilcher *et al.*, 1972; Hirons and Edwards, 1986; Edwards and McIntosh, 1988; Robinson and Dickson, 1988; Whittington *et al.*, 1991). In the pollen data resulting from this study, the earlier *Ulmus* declines at A'Chrannag and Livingstone's Cave, Ulva and Loch an t'Suidhe, Mull do not coincide with substantial evidence of human activity. Increases in microcopic charcoal in AC1 at A'Chrannag c. 4600 BP (3440 cal. BC) probably relate to the burning of heathland and occur after the main *Ulmus* decline.

As Neolithic land use intensified, then elm populations already under pressure from the effects of climate and soil deterioration would be placed under greater pressure. The later and secondary *Ulmus* declines in the Inner Hebridean pollen record may therefore be more closely linked to human impact than earlier occurrences, and from c. 4000 BP (2530 cal. BC) there is a broad range of evidence for cereal cultivation and grazing. Cereal-type pollen occurs in some pollen profiles at or before the *Ulmus* declines (Livingstone's Cave, Ulva; Loch a'Bhogaidh, Islay; Rhoin Farm, Aros Moss, Arran) and carbonized cereal remains were found in a Neolithic context in Livingstone's Cave, Ulva (Bonsall *et al.*, 1991). Herbs and *Calluna* expand in many pollen profiles, and increases in *Plantago lanceolata* may result from the pressure of grazing of domestic animals. Microscopic charcoal rises with these later *Ulmus* declines, but may result from an increased fallout from domestic fires linked to more widespread occupation and increasing populations. In the later *Ulmus* declines from most sites reductions in other arboreal taxa are evident, representing the opening of woodland as cultivation and grazing increases. Turner *et al.*, (1993) find asynchronous and relatively late elm declines in profiles in a small area from the North York Moors which are attributed to the response of elm to human impacts and disease.

7.5.4 Pathogenic attack

Disease has frequently been cited as a possible mechanism for the reduction of Ulmus in pollen spectra from the British Isles. Finds of the elm bark beetle (*Scolytus scolytus*) in elm decline deposits at Hampstead Heath, London led Girling and Greig (1985) to propose that Dutch elm disease (carried by the beetle) could be responsible for the classical elm decline of c. 5000 BP (4010 cal. BC). However, *Scotlytus scolytus* only attacks trees already under stress, and if Dutch elm disease or other pathogens influenced the *Ulmus* decline, then these were probably secondary to the effects of climate, soil deterioration and possibly human activity.

7.5.5 Summary of evidence for the *Ulmus* declines

Although the Inner Hebridean pollen profiles with dated *Ulmus* declines are limited in number, the problems of the identification of possible causes and the complexities of interpretation are evident. Multiple profiles from Ulva indicate that exposure and local ecological factors may have had a greater influence on *Ulmus* than previously suggested. The widely differing dates for the *Ulmus* declines in A'Chrannag and Livingstone's Cave profiles on Ulva demonstrate how multiple profiles can be used to detect numerous *Ulmus* declines. It may therefore be useful to extend all the Loch a'Bhogaidh profiles to cover the *Ulmus* declines, and obtain dates for these. Currently, only LABI from Loch a'Bhogaidh shows an *Ulmus* decline.

Although the range of dates attributed to the elm declines at different sites in the Inner Hebrides may partly be due to inaccuracies in radiometric dating and standard deviation, there is nevertheless a suggestion that local environmental influences, which may include exposure, soil type and human impact, were all significant in affecting *Ulmus* in addition to climate. As Whittington *et al.*, (1991:85) concluded:

"a myriad of local factors could be evoked to explain the behaviour of elm pollen curves."

The variation in the timings of the *Ulmus* declines and the detection of multiple declines at many sites means that reference to 'the elm decline' as a dating horizon and an indicator of changing prehistoric cultures may be misleading (Whittington *et al.*, 1991). The array of dates for the *Ulmus* declines in the Inner Hebrides and the different patterns in the *Ulmus* profiles demand more detailed records for this taxon. Implicit in this is the necessity for more multiple profile studies to assess the intra-site representations of *Ulmus* which may provide a clearer indication of the cause or causes of the elm decline.

7.6 Summary of pollen records for the Inner Hebrides, western Scotland, and the Outer Hebrides

The pollen data discussed above indicate that a range of vegetation types was present at various times in different locations in the west of Scotland and its islands. In the Inner Hebrides, human impacts on vegetation may have occurred from as early as c. 8500 BP (7470 cal. BC) and much of the dated evidence for human activity coincides with dates for the occupation of archaeological sites. There is also evidence for Mesolithic activity in the Outer Hebrides, although this may be less convincing, but little from sites on the mainland, probably due to the lack of detailed pollen diagrams. Neolithic impacts appear to be more widespread throughout the region, although these are more easily detected in pollen profiles than small scale, transient Mesolithic disturbances.

The different chronologies for the expansion of various arboreal taxa in the region challenges current perceptions regarding their early Holocene behaviour and the data highlight the complex ecological factors which may have influenced changing patterns of vegetation in the region.

CHAPTER 8 - REVIEW OF METHODS AND IMPLICATIONS OF RESULTS FOR FUTURE RESEARCH

8.1 Review of methods

Chapter 2 detailed the methodologies to be employed in undertaking this research and highlighted the importance of multiple profiles in palynological investigations. Implicit in this is the employment of close resolution sampling and radiocarbon AMS dating. The quantification of microscopic charcoal, assessment of damaged pollen types and scanning for cereal-type pollen were also advocated as useful tools for palaeoecological investigation. The inclusion of the above methods allows an assessment of the usefulness of each in the context of this and future studies.

8.1.1 Multiple profiles

Multiple profile studies in the Inner Hebrides were previously limited to Loch a'Bhogiadh, Islay and Machrie Moor, Arran, but two of the three cores from Loch a'Bhogaidh were undated and no synthesis of the Machrie Moor profiles has been published. Additional profiles from Loch a'Bhogaidh, Islay, Kinloch, Rum and four profiles from Ulva increase the range of multiple profile studies in the islands.

Similarities and differences in intra-site profiles for the same taxon (in percentage and influx terms) can assist in explaining the behaviour of a taxon, and may be useful in detecting anomalies within individual profiles. This is demonstrated by the Loch a'Bhogaidh profiles, where an earlier *Corylus* rise is suggested by the central profile, LABI, compared to surrounding profiles which often lay closer to the loch margins. Although the basal radiocarbon dates from LABI are subject to obvious error, the different characteristics of the early LABI *Corylus* profile compared to the others from the site indicate that LABI received a greater amount of *Corylus* pollen from a wider region. The LABI profile may therefore reflect the dynamics of *Corylus* prior to its actual expansion at Loch a'Bhogaidh.

Although A'Chrannag bog and Livingstone's Cave bog, Ulva are different basins, these display marked differences in taxon assemblages, and the differential behaviour of the respective *Ulmus* curves between the two basins at what could be similar times (e.g. c. 5100 BP [4010 cal. BC], c. 4800 BP [3570 cal. BC], c. 3800 BP [2220 cal. BC]) demonstrates the potential for multiple profiles as an aid to determining taxon behaviour.

It was suggested in Chapter 2 that multiple profile studies may assist in determining whether features in the pollen profiles were of natural or human origin. Although in many instances interpretation remains speculative, such as for the small reductions in *Corylus* in the Loch a'Bhogaidh profiles prior to c. 7800 BP (6650 cal. BC), in other cases interpretation of features may be enhanced. This is certainly the case for the main phase of *Corylus* reduction at Loch a'Bhogaidh from c. 7700 - 7000 BP (6600 - 5870 cal. BC), which appeared less clearly in the central profile LABI due to its central position, greater depth and lower sampling resolution. Although Edwards and Berridge (1994) mentioned the possibility that this could be a reflection of Mesolithic impacts, this is now inferred as reflecting a period of climatic cooling (Alley *et al.*, 1997; Barber *et al.*, 1999; Willemse and Törnqvist, 1999), although multiple profiles indicate that some human impact may have exacerbated the effects of climate in the latter part of the climatic event.

The final episode of woodland reduction at Kinloch is confirmed as being largely the result of human activity, as multiple profiles indicate a progression from east to west, starting close to the known site of human occupation.

There are two aspects to the potential for representations of spatial variation in vegetation offered by multiple profiles. Differences may occur between the overall representations of individual taxa, such that percentages, concentrations and influx rates for a single taxon are markedly different between profiles. The other aspect is that different representations of single features of disturbance in the profiles may be detected.

In the two profiles from A'Chrannag basin, Ulva, there are distinctly different percentage, concentration and influx representations in some arboreal taxa which suggests that very different vegetational communities occurred in different parts of the bog and surrounding area. For most of the sampled AC1 profile, *Betula* is dominant and exceeds 80 % TLP. For the comparable part of the AC2 profile, *Betula* averages 30 % TLP, but *Alnus* reaches percentages of 100 % TLP in AC2 compared with c. 30 % TLP in AC1. Concentrations and influx rates for these taxa display similar patterns to the percentage profiles.

In contrast to the above, the Loch a'Bhogaidh percentage and absolute profiles have uniform representation for the major arboreal taxa, especially and predominantly *Corylus*. The predominance of *Corylus*, particularly in the early parts of the profiles, may be partially responsible for this by reducing the pollen counts of other taxa to background levels which may be fairly consistent in percentage terms over long periods of time. Sediment accumulation may also have contributed to the homogenisation of the fossil pollen assemblage within the lake basin. Nevertheless, there do appear to be both small and large scale disturbances in the *Corylus* and other taxon curves from Loch a'Bhogaidh and these are differentially represented between the profiles. The *Corylus* reduction which occurs between c. 7700 BP and c. 7000 BP (6600 - 5840 cal. BC) at Loch a'Bhogaidh is of particular note.

The profiles covering this event indicate that the source of the *Corylus* reduction changed from the northwest to the southeast of the basin at c. 7300 BP (6190 cal. BC) and in this context spatial variation in the *Corylus* and other profiles is apparent. At Kinloch, Rum, a reduction in woodland c. 3900 BP (2370 cal. BC) was initially greatest to the east of the mire, close to the known site of human occupation, and woodland may have persisted for several hundred years later than this to the west of the site. However, the lack of radiocarbon dates in the profiles restricts confidence in this interpretation, and highlights the need for the application of AMS dates in multiple profile studies.

On Ulva, the profiles from two different basins indicate that approximately 1 km to the north of the known site of human occupation, burning to promote the continued renewal of heathland could have occurred between c. 4400 and c. 4000 BP (3120 and 2530 cal. BC). Nearer the site of occupation, the pollen indicates that small scale woodland clearances occurred within the same time period, probably to increase grazing for livestock and allow cereal cultivation which is also indicated in the pollen profiles and by the presence of cereal macrofossils at the occupation site.

These examples illustrate the range of variation in vegetation which may be detected through multiple coring , both in lake sediments and peat. There is no reason to suggest that multiple profiles from lake sediments are any less useful than those from peat (cf. Jackson, 1994). Overall, multiple profiles appear to be very effective in reconstructing vegetation histories, their variations, and differential behaviour of a single taxon in several pollen curves may assist in identifiying its ecological requirements in the early Holocene.

8.1.2 AMS dates

Radiocarbon dates are obviously needed in the context of multiple profiles to ensure cross correlation, but the absence of well-dated profiles for many pollen cores from western Scotland and the Inner Hebrides makes comparisons difficult (Chapter 7). AMS dates are preferable to enable the correlation of profiles which have close sampling resolutions, as thinner, smaller samples are taken for AMS dating.

The absence of a suite of AMS dates for each profile from Kinloch, Rum means that the interpretation of a progressive east-west woodland reduction from c. 3900 BP (2370 cal. BC) is based on assumption, and more dates on all the profiles would strengthen the arguments for this.

In some of the profiles with many AMS dates, reversals in dates (at AC1, Ulva) and what appear to be erroneous dates (at LABIII, Loch a'Bhogaidh), are problematic, but well-dated multiple profiles have assisted in detecting and explaining these. For example, dates on LABIIIc at Loch a'Bhogaidh appear to be too early when compared to other dated profiles from the site, but would have appeared reasonable had this been the only core. Similarly, had only a single profile from Livingstone's Cave basin been dated, then one of the Holocene basal dates on either of the cores would probably have been considered acceptable and used in interpretation.

8.1.3 Microscopic charcoal quantification

Microscopic charcoal quantification is an important element of palaeoecological investigation, and charcoal concentrations, Ch:P and, where possible, charcoal influx were calculated for each of the profiles. The different methods of quantification provide results which would lead to similar interpretations. Although at Livingstone's Cave bog on Ulva, charcoal influx is extremely low in comparison to concentrations and Ch:P, it nevertheless shows the same declines and increases as these.

Although the continued presence of microscopic charcoal in most of the profiles suggests a continued fallout of particulates - probably derived from fires occurring over a wide, regional area - peaks in charcoal within the profiles probably reflect local fires.

This is certainly indicated by profiles from Ulva, where increases in charcoal linked to fires in heathland appear in AC1 in the A'Chrannag basin, but not in the corresponding parts of AC2 from the same basin, or in corresponding parts of profiles from Livingstone's Cave basin. If this charcoal was derived from an increase in fires over a wide region, then increases in charcoal in all profiles could be expected.

Microscopic charcoal analyses in the Loch an t'Suidhe profile also enhance interpretation of events recorded in the pollen curves. In particular, large increases in charcoal are recorded in the new profile, whereas in the original Lowe and Walker (1986a and b) profile, charcoal is not recorded although a reduction in arboreal pollen and expansion in grasses is detected despite the low sampling resolution. Although the episode may reflect vegetation responses to a colder, dryer climate (Alley *et al.*, 1997) and the increased charcoal could be the result of increased natural fires in a dry climate, the charcoal increases may also reflect a human presence. Spatial and temporal changes in the microscopic charcoal profiles at Loch a'Bhogaidh coincide with changes in the pollen curves for a similar period to that at Loch an t'Suidhe, but suggest that human action could have contributed to a reduction in arboreal vegetation at this site. Archaeological evidence suggests a strong Mesolithic presence in the Inner Hebrides, thus the increases in microscopic charcoal between c. 7900 BP and c. 6850 BP (6810 and 5870 cal. BC) at Loch an t'Suidhe could also have arisen from human actions as well as arising from natural events.

Although the taphonomy of microscopic charcoal is not fully understood (Section 2.1.2), when combined with pollen data, microscopic charcoal aids interpretation to some extent. Although a persistent presence of charcoal is usually recorded, peaks in the microscopic charcoal curves appear to represent localised fire events in many cases, and often reinforce or enhance interpretations of the pollen profiles. Also, the more frequently microscopic charcoal is quantified in palaeoecological analysis, the more information may be acquired about its taphonomy and the role of fires in past ecosystems.

8.1.4 Damaged pollen analysis

The results of the identification and quantification of damaged pollen types were included in the profile interpretations in previous chapters. The type of damage most frequently recorded was that of pitted grains. Thinned pollen was scarcely detected, and broken and crumpled grains occurred mainly in pollen types of high susceptibility to such damage. For example, *Pinus* pollen is mainly broken and contributes to a high percentage of the total broken pollen of each sample. Crumpled pollen, (given the exclusion of Cyperaceae from this category) is represented mainly by Poaceae which crumples easily.

Although total damaged pollen percentages and the ratio of damaged to undamaged pollen increase in most cases when reductions in arboreal pollen occur and erosion may be indicated, given the lack of variation in damage type, there is no evidence to suggest that one type of damage has a specific cause. Pitting is normally ascribed to aerobic oxidation and fungal action when a grain is exposed at the sediment surface prior to burial. It is possible that long distance transport may expose pollen grains to damage of this nature. There appears to be a general level of 'background noise' for damaged, particularly pitted, pollen recorded in each profile, and normal taphonomic processes will result in a proportion of pollen being damaged. Nevertheless, damaged pollen quantification may be useful to ascertain whether, for certain periods of time, the pollen of one taxon has arrived at a site by a different taphonomic route than others.

Although damaged pollen profiles may be used as an interpretative tool, their main function appears to be limited to reinforcing the main palynological, LOI and microscopic charcoal data. In some instances, where reductions in arboreal pollen are evident, there are no increases in damaged pollen percentages (e.g. Loch an t'Suidhe), and the behaviour of damaged pollen does not always follow expected patterns. The processes which lead to the different types of damage in pollen grains need to be better understood before firmer concusions can be drawn.

8.1.5 Cereal scanning and identification

The method of low-power scanning of contiguous samples for cereal-type pollen resulted in the detection of additional cereal-type grains which would not have been discovered during routine counting. The main problem encountered was low TLP concentrations in some samples, which meant that only low pollen counts were scanned in some samples and made it difficult to establish a fixed amount of grains to scan. However, the main problem lies not with the detection of cereal-type pollen, but its identification. Most of the cereal-type pollen detected fell within the *Hordeum*-type category and could be the pollen of large grasses rather than cultivated plants. Although the archaeological confirmation of a contemporaneous human presence for cereal-type pollen detected in this study suggests that this is *Hordeum*, the evidence is circumstantial and caution in interpretation is still needed. In pollen studies where no archaeological evidence is available to reinforce interpretations, then these must remain even more circumspect.

8.2 Conclusions and implications of results for future research

The above indicates that multiple coring of single sites is able to provide a much clearer reconstruction of local vegetation than a single profile, although close resolution sampling and a suite of AMS dates are necessary to formulate any valid conclusions. Interpretations may also be enhanced by incorporating additional techniques such as charcoal quantification, damaged pollen analysis, and low-power scanning for cereal-type pollen in a multiple profile study.

The previous chapter summarised the palaeoecological data produced from the Inner Hebrides, Outer Hebrides and the west coast of Scotland. The multiple profile studies undertaken in this programme of research provide a greater insight into the early Holocene behaviour of the major arboreal taxa in the Inner Hebrides. Nevertheless, the data are limited to a few islands and many more sites from Mull and Skye, as well as the smaller islands of Canna, Eigg and Muck, are required to fully appreciate the ecological dynamics of early Holocene woodlands in the archipelago.

Multiple profiles from more sites may assist in identifying the impacts of climatic changes, and well dated multiple profiles over a range of latitudes from western Scotland and its islands may be compared to those from the eastern Scotland to assess the degree of impact which climate may have in different environmental settings. It may also be useful to apply palaeomagnetic analysis to multiple pollen cores from lake sediments, as this may assist in determining the processes acting within the lake and which may have affected pollen distribution.

The explanation for the rapidly attained high levels of *Corylus* in western Scotland and the Inner Hebrides in the early Holocene remains largely unanswered. Whilst multiple profiles from areas of Skye and Mull in addition to the smaller islands may clarify matters, this should probably be combined with landscape scale investigations of soil development and chemistry, and studies of local meteorological conditions influenced by topography, in addition to climatic data. Also of note in this study are the various timings for the *Ulmus* decline at the different sites. The complex range of factors surrounding the *Ulmus* decline is very much established, but multiple profile studies from a wider area of western Scotland could provide greater detail about ecological influences on *Ulmus* and its reactions to these in different environments. Inter-disciplinary studies such as those suggested for investigation the *Corylus* rise should also be applied.

Although there are many pollen profiles from Skye and Mull, these are single cores, often with low resolution sampling, and lacking records of microscopic charcoal. Most will be centrally located in the site basin which means that their pollen may be derived from a wide region and is not representative of local vegetation, especially in lake profiles. Single cores, particularly those which are centrally positioned, may mean that evidence of human impact is less likely to be detected and multiple profiles would increase detection rates in addition to possibly representing such events in greater detail.

The current lack of evidence for early Holocene human impacts in profiles from the west coast of Scotland may be corrected by future multiple profile studies. Mesolithic and Neolithic archaeology confirms the presence of people, particularly in the Oban area and Kintyre peninsula, and further multiple profile investigations in these areas would provide material for comparison with that from the Inner Hebrides. Similar investigations would also be appropriate in the Outer Hebrides where human impact may be more difficult to discern.

The pollen evidence obtained as part of this study may also be used to identify areas for archaeological investigation. The Mesolithic activity suggested in the Loch an t'Suidhe profile occurs in an area where there are currently no Mesolithic finds, and it may be appropriate to direct future fieldwalking activities in the Bunessan area. There is certainly a need to find more Mesolithic archaeology on Mull, which this island lacks compared to the other Inner Hebridean islands. Future discoveries of archaeological material could also influence the choice of sites for pollen analysis in the future.

Although the pollen data from this study has provided a great deal of detail for the palaeoecology of specific sites in the Inner Hebrides, comparison of these sites with others in the wider region is difficult due to differences in the quality of data from the various studies. The data from multiple profile studies are able to provide firmer interpretations than those from single profiles, but a greater knowledge of the taphonomic processes affecting pollen and charcoal, and landscape studies of soils within a catchment may improve the interpretation of multiple profiles in the future.

BIBLIOGRAPHY

Aaby, B., 1986. Palaeoecological studies of mires. In Berglund, B.E. (ed.), *Handbook of Holocene Palaeoecology and Palaeohydrology.* 145 - 164. Chichester: John Wiley and Sons.

Affleck, T.A., Edwards, K. and Clarke, A., 1988. Archaeological and palynological studies at the Mesolithic pitchstone and flint site of Auchareoch, Isle of Arran. *Proceedings of the Society of Antiquaries of Scotland* 118, 37-59.

Agnew, A.D.Q., Edwards, K.J., Hirons, K.R., Hulme, P.D. and Proctor, M.C.F.,1988. The Mire of Loch a'Bhogaidh, Islay. *Transactions of the Botanical Society of Edinburgh* 45, 187-201.

Alley, R.B., Mayewski, P.A., Sowers, T., Stuiver, M., Taylor, K.C. and Clark, P.U., 1997. Holocene Climatic Instability: A prominent, widespread event 8200 yr. ago. *Geology* 25, 483 - 486.

Andersen, S.T., 1979. Identification of wild grass and cereal pollen. *Danmarks Geologiske Undersogelse Årbog 1978*, 69-72.

Andrews, M.V., Beck, R.B., Gilbertson, D.D. and Switsur, V.R., 1987. The Past and Present Vegetation on Oronsay and Colonsay, Section B: Palaeoenvironmental Investigations. In Mellars, P., *Excavations on Oronsay.* Edinburgh: Edinburgh University Press, 57-71.

Armit, I., 1996. The Transition to Agriculture 3: Scotland. In Pollard, T. and Morrison, A., (eds.) *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press. 280-291.

Armit, I. and Finlayson, W.F., 1992. Hunter-gatherers transformed: the transition to agriculture in northern and western Europe. *Antiquity* 66, 664-676.

Ashmore, P.J., 1996. *Neolithic and Bronze Age Scotland.* London: B.T. Batsford Ltd.

Ball, M.E., 1983. Native Woodlands of the Inner Hebrides. *Proceedings of the Royal Society of Edinburgh* 83B; 319-340.

Ball, M.E., 1987. Botany, Woodland and Forestry. In Clutton-Brock, T.H. and Ball, M.E. (eds.), *Rhum: The Natural History of an Island.* Edinburgh; Edinburgh University Press, 43-62.

Ballantyne, C.K. and Dawson, A.G., 1997. Geomorphology and Landscape Change. In Edwards, K.J. and Ralston, I.B.M. (eds), *Scotland: Environment and Archaeology, 8000 BC - AD 1000.* Chichester, John Wiley and Sons Ltd., 23-44.

Ballantyne, C.K. and Wain-Hobson, 1980. The Loch Lomond Advance on the Island of Rhum. *Scottish Journal of Geology* 16, 1-10.

Bangerter, E.B. and Cannon, J.F.M., 1978. Selected distribution patterns shown by the vascular plants 2.2. In Jermy, A.C. and Crabbe, J.A. (eds.), *The Island of Mull: a survey of its flora and environment.* London: British Museum (Natural History).

Barber, D.C., Dyke, A., Hillaire-Marcel, C., Jennings, A.E., Andrews, J.T., Kerwin, M.W., Bilodeau, G., McNeely, R., Southons, J., Morehead, M.D. and Gagnon, J.-M., 1999. Forcing of the cold event of 8,200 years ago by catastrophic drainage of Laurentide lakes. *Nature* 400, 22/7/99, 344-348.

Barclay, G.J., 1996. The Neolithic. In Edwards, K.J. and Ralston, I.B.M. (eds), *Scotland: Environment and Archaeology, 8000 BC - AD 1000.* Chichester, John Wiley and Sons Ltd., 127-150.

Bartlein, P.J. and Prentice, I.C., 1989. Orbital variations, climate and palaeoecology. *Trends in Ecology and Evolution* 4, 195-199.

Batey, C.E. (ed.), 1993. *Discovery and Excavation in Scotland: An Annual Survey of Scottish Archaeological Discoveries, Excavation and Fieldwork.* Council for Scottish Archaeology, Edinburgh.

Bengtsen, L. and Enell, M., 1986. Chemical Analysis. Berglund, B.E., *Handbook of Holocene Palaeoecology and Palaeohydrology.* Chichester: John Wiley and Sons.

Bennett, K.D., 1983. Postglacial population expansion of forest trees in Norfolk, UK. *Nature* 303, 164-167.

Bennett, K.D., 1984. The post-glacial history of *Pinus sylvestris* in the British Isles. *Quaternary Science Reviews* 3, p.133-155.

Bennett, K.D., 1988. Post-glacial vegetation history: ecological considerations. In Huntley, B. and Webb, T. III (eds.), *Vegetation History.* Dordrecht: Kluwer Academic Publishers 699-724.

Bennett, K.D., 1989. Postglacial vegetation history of the Rhinns of Islay. In Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project, 2nd interim report,* Unpublished.

Bennett, K.D., 1994. Annotated catalogue of pollen and pteridophyte spore types of the British Isles. *http/www. kv.geo.uu.se/pc-intro.html*

Bennett, K.D.,1996. Late-Quaternary Vegetation Dynamics of the Cairngorms. *Botanical Journal of Scotland*, 48, 51- 63.

Bennett, K.D. and Birks, H.J.B., 1990. Postglacial history of alder (*Alnus glutinosa* (L.) Gaertn.) in the British Isles. *Journal of Quaternary Science* 5, 123-133.

Bennett, K.D., Boreham, S., Sharp, M.J. and Switsur, V.R., 1992. Holocene history of environment, vegetation and human settlement on Catta Ness, Lunnasting, Shetland. *Journal of Ecology* 80, 241-273.

Bennett, K.A., Fossitt, J.A., Sharp, M.J. and Switsur, V.R., 1990. Holocene vegetational and environmental history at Loch Lang, South Uist, Western Isles, Scotland. *New Phytologist* 114, 281-298.

Bennett, K.D. and Lamb, H.F., 1984. The history of pine and oak in S.W. Scotland. *British Geological Society Bulletin* 5, 16-17.

Bennett, K.D., Whittington, G. and Edwards, K.J., 1994. Recent Plant Nomenclature Changes and Pollen Morphology in the British Isles. *Quaternary Newsletter* June 1994, 1-6.

Birks, H.H., 1984. Late-Quaternary pollen and plant macrofossil stratigraphy at Lochan an Druim, north-west Scotland. Haworth, E.Y. and Lund, J.W.G. (eds.*), Lake Sediments and Environmental History.* Leicester University Press.

Birks, H.J.B., 1970. Inwashed pollen spectra at Loch Fada, Isle of Skye. *New Phytologist* 69, 807 - 820.

Birks, H.J.B., 1973. *Past and Present Vegetation of the Isle of Skye. A Palaeoecological Study.* Cambridge: CUP.

Birks, H.J.B., 1980. *Quaternary Vegetation History of West Scotland.* Fifth International Palynological Conference, Guidebook for Excursion C8. Cambridge.

Birks, H.J.B., 1987. The Past and Present Vegetation of Oronsay and Colonsay, Section A. Mellars, P., *Excavations on Oronsay.* Edinburgh: Edinburgh University Press.

Birks, H.J.B., 1989. Holocene isochrone maps and patterns of tree-spreading in the British Isles. *Journal of Biogeography* 16, 503-540.

Birks, H.J.B., 1990. Changes in vegetation climated during the Holocene of Europe. Boer, M.M. and DeGroot, R.S. (eds.), *Landscape-Ecological impact of climatic change.* Amsterdam: IOS Press, 133-158.

Birks, H.J.B., 1993. Loch Ashik, Loch Cleat and Loch Meodal. In Gordon, J.E. and Sutherland, D.G. (eds.), *Quaternary of Scotland.* London: Chapman and Hall, 399-407.

Birks, H.J.B. and Madsden, B.J., 1979. Flandrian vegetational history of Little Loch Roag, Isle of Lewis, Scotland. *Journal of Ecology* 67, 825-842.

Birks, H.J.B. and Williams, W., 1983. Late-Quaternary vegetational history of the Inner Hebrides. *Proceedings of the Royal Society of Edinburgh* 83B, 269-292.

Böhncke, S.J.P., 1988. Vegetation and Habitation History of the Callanish Area, Isle of Lewis, Scotland. In Birks, H.H., Birks, H.J.B., Karland, P.E. and Moe, D.(eds.*), The Cultural Landscape: Past Present and Future.* Cambridge: Cambridge University Press, 445-461.

Bonny, A.P., 1978. The effect of pollen recruitment processes on pollen distribution over the sediment surface of a small lake in Cumbria. *Journal of Ecology* 66, 385-416.

Bonsall, C., 1996. The 'Obanian Problem': Coastal Adaptation in the Mesolithic of Western Scotland. In Pollard, T. and Morrison, A., (eds.) *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 183-197.

Bonsall, C. and Smith, C., 1990. Bone and antler technology in the British Late Upper Palaeolithic and Mesolithic: the impact of accelerator dating. In Vermeersch, P.M. and Van Peer, P., (eds.), *Contributions to the Mesolithic in Europe.* Leuvenileaven University Press, 359-368.

Bonsall, C., Sutherland, D.G., Lawson, T.J. and Russell, N.J., 1991. Excavations in Ulva Cave, western Scotland 1989: a preliminary report. *Mesolithic Miscellany* 13, 7-13.

Bonsall, C., Sutherland, D.G., Lawson, T.J., Russell, N.J. and Barnetson, L., 1989. *Ulva Cave: Excavation Report No. 2.* University of Edinburgh, Department of Archaeology. Unpublished.

Bonsall, C., Sutherland, D.G., Russell, N.J., Coles, G., Paul, C.R.C., Huntley, J. and Lawson, T.J., 1995. Excavations in Ulva Cave, western Scotland 1990-91: a preliminary report. *Mesolithic Miscellany* 15, 8-21.

Bos, J.A.A. and Janssen, C.R.,1996. Local Impact of Palaeolithic Man on the Environment During the End of the Last Glacial in the Netherlands. *Journal of Archaeological Science* 23, 731-739.

Boyd, J.M. and Boyd, I.L., 1990. *The Hebrides: A Natural History.* London: William Collins Sons and Co.

Boyd, W.E., 1988. Early Flandrian vegetational development on the coastal plain of north Ayrshire, Scotland: evidence from multiple pollen profiles. *Journal of Biogeography* 15, 325-337.

Boyd, W.E. and Dickson, J.H., 1986. Patterns in the Geographical Distribution of the Early Flandrian *Corylus* rise in southwest Scotland. *New Phytologist* 102, 615-623.

Bradbury, J.P., Tarapchak, S.J., Waddington, J.C.B. and Wright, R.F., 1975. The impact of forest fire on a wilderness lake in northeastern Minnesota. *Verhandlungen Internationales Vereinigung für Limnologie* 19, 875 - 883.

Bradbury, J.P., 1996. Charcoal deposition and redeposition in Elk Lake, Minnesota, USA. In *The Holocene* 6, 339-344.

Bradshaw, R.H. and Browne, P., 1987. Changing patterns in the post-glacial distribution of Pinus sylvestris in Ireland. *Journal of Biogeography* 14, 237-248.

Brush, G.S. and Brush, L.M., Jr., 1972. Transport of pollen in a sediment-laden channel: a laboratory study. *American Journal of Science* 272, 359-381.

Buckland, P.C. and Edwards, K.J., 1984. The longevity of pastoral episodes of clearance activity in pollen diagrams: the role of post-occupation grazing. *Journal of Biogeography* 11, 243-249.

Bunting, M.J., 1994. Vegetation history of Orkney, Scotland; pollen records from two small basins in west Mainland. *New Phytologist*, 128, 771-792.

Bunting, M.J. and Davies, A.L., in press. Pollen from Loch Gorm, Islay. In Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project.* Cambridge: MacDonald Institute Monographs.

Campbell, I.D., 1991. Experimental mechanical destruction of pollen grains. *Palynology* 15, 29 - 33.

Campbell, I.D. and Campbell, C., 1994. Pollen preservation: experimental wet-dry cycles in saline and desalinated sediments. *Palynology* 18, 5 - 10.

Carp, E., 1994. The pollen sequence from the Upper section at Coulererach. In Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project 1994 (7th) Interim Report.* Dept. of Archaeology, University of Reading, 71-72.

Carruthers, W., 1994. The charred plant remains from Feature 24, Staosnaig: A preliminary assessment. In Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project 1994 (7th) Interim Report.* Dept. of Archaeology, University of Reading, 98-101.

Caseldine, C., 1991. Surface pollen studies across Bankhead Moss, Fife, Scotland. *Journal of Biogeography* 8, 7-25.

Caseldine, C. and Hatton, J., 1993. The development of high moorland on Dartmorr: fire and the influence of Mesolithic activity on vegetation change. In Chambers, F.M., *Climate Change and Human Impact on the Landscape.* London: Chapman and Hall, 119-132.

Chambers, F.M. and Elliott, L., 1989. Spread and expansion of *Alnus* Mill. in the British Isles: timing, agencies and possible vectors. *Journal of Biogeography* 16, 541-550.

Chen, Y., 1987. Pollen and sediment distribution in a small crater lake in Northeast Queensland, Australia. *Pollen et Spores* 28, 89 - 110.

Clark, J.S., 1988. Particle Motion and the Theory of Charcoal Analysis: Source Area, Transport, Deposition and Sampling. *Quaternary Research* 30, 67-80.

Clark, J.S., Merkt, J. and Müller, H., 1989. Post-glacial fire, vegetation and human history on the northern alpine forelands, south-western Germany. *Journal of Ecology* 77, 897-925.

Clark, R.L., 1982. Point count estimation of charcoal in pollen preparations and thin sections of sediments. *Pollen et Spores*, Vol. 24, No. 3-4, 523-535.

Clutton-Brock, T.H. and Ball, M.E., 1987. Introduction. In Clutton-Brock, T.H. and Ball, M.E.(es.), *Rhum: The Natural History of an Island.* Edinburgh; Edinburgh University Press, 1-10.

Coles, B.J., 1998. Doggerland: a speculative survey. *Proceedings of the Prehistoric Society* 64, 45-81.

Coles, J.M., 1971. The early settlement of Scotland: excavations at Morton, Fife. *Proceedings of the Prehistoric Society* 37, 284-366.

Currie, A. and Murray, C., 1983. Flora and Vegetation of the Inner Hebrides. *Proceedings of the Royal Society of Edinburgh* 83B; 293-318.

Cushing, E.J., 1964. Redeposited pollen in Late Wisconsin pollen spectra from east-central Minnesota. *Amercian Journal of Science* 262, 1075-1088.

Cushing, E.J., 1967. Evidence for differential pollen preservation in late Quaternary sediments in Minnesota. *Review of Palaeobotany and Palynology,* 4, 87 - 101.

Dalland, M., 1997. Radiocarbon dates from Fife Ness. In Turner, R. (ed.), *Discovery and Excavation in Scotland.* Edinburgh: Council for Scottish Archaeology, 113.

Davis, M.B., 1973. Redeposition of pollen grains in lake sediment. *Limnology and Oceanography* 18, 44-52.

Davis, M.B. and Brubaker, L. B., 1973. Differential sedimentation of pollen grains in lakes. *Limnology and Oceanography* 18, 635-646.

Davis, M.B., Moeller, R.E. and Ford, J., 1984. Sediment focusing and pollen influx. Haworth, E.Y. and Lund, J.W.G. (eds.), *Lake Sediments and Environmental History.* Leicester University Press.

Davis, R.B., Brewster, L.A. and Sutherland, J., 1969. Variation in pollen spectra within lakes. *Pollen et Spores* 11, 557-571.

Dawson, 1984. Quaternary sea-level changes in western Scotland. *Quaternary Science Reviews* 3, 345-368.

Dawson, A. and Dawson, S., 1994. Late Pleistocene and Early Holocene Sea level change on Islay. Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project 1994 (7th) Interim Report.* Dept. of Archaeology, University of Reading, 61-70.

Day, P., 1996. Devensian Late-glacial and early Flandrian environmental history of the Vale of Pickering, Yorkshire, England. *Journal of Quaternary Science* 11, 9-24.

Douglas Price, T., 1990. The Reconstruction of Mesolithic Diets. In Bonsall C. (ed.), *The Mesolithic in Europe.* Edinburgh: John Donald Publishers, 48-59.

Dubois, A.D. and Ferguson, D.K., 1985. The climatic history of pine in the Cairngorms based on radiocarbon dates and stable isotope analysis, with an account of the events leading up to its colonization. *Review of Palaeobotany and Palynology* 46, 55-80.

Edwards, K.J., 1981. The seperation of *Corylus* and *Myrica* pollen in modern fossil samples. *Pollen et Spores* 23, No. 2, 205-218.

Edwards, K.J., 1982. Man, space and the woodland edge: speculations on the detection and interpretation of human impact in pollen profiles. In Bell, M. and Limbrey, S. (eds.), *Archaeological Aspects of Woodland Ecology.* BAR Int. Series 146, 5-22.

Edwards, K.J., 1983. Quaternary palynology: multiple profile studies and pollen variability. *Progress in Physical Geography* Vol. 7, 587-609.

Edwards, K.J., 1988. The Hunter-Gatherer/Agricultural Transition and the pollen record in the British Isles. In Birks, H.H., Birks, H.J.B., Karland, P.E. and Moe, D.(eds.), *The Cultural Landscape: Past Present and Future.* Cambridge: C.U.P.,255-266.

Edwards, K.J., 1989. Meso-Neolithic Vegetational Impacts in Scotland and Beyond: Palynological Considerations. In Bonsall, C. (ed.), *The Mesolithic in Europe.* Edinburgh: John Donald Publishers Ltd.

Edwards, K.J., 1990. Fire and the Scottish Mesolithic: Evidence from Microscopic Charcoal. Versmeersch, P.M. and Van Peer, P, (eds.), *Contributions to the Mesolithic in Europe,* Leuven: Leuven University Press, 71-79.

Edwards, K.J., 1991. Spatial scale and palynology: a commentary on Bradshaw. In Harris, D.R. and Thomas, K.D. (eds.), *Modelling ecological change.* London: Institute of Archaeology, University College London, 53-59.

Edwards, K.J., 1996. A Mesolithic of the Western and Northern Isles of Scotland? Evidence from Pollen and Charcoal. In Pollard, T. and Morrison, A., (eds.) *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 23-38.

Edwards, K.J., in press. Vegetation history of the southern Inner Hebrides during the Mesolithic period. In Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project,* Cambridge; MacDonald Institute Monographs.

Edwards, K.J., Ansell, M. and Carter, B.A., 1983. New Mesolithic Sites in south-west Scotland and their importance as indicators of inland penetration. *Transactions of the Dumfrieshire and Galloway Natural History and Antiquarian Society* 8, 9-15.

Edwards, K.J. and Berridge, J.M.A., 1994. The Late-Quaternary vegetational history of Loch a'Bhogaidh, Rinns of Islay S.S.S.I., Scotland. *New Phytologist* 128, 749-769.

Edwards, K.J. and Hirons, K.R., 1984. Cereal pollen grains in pre-elm decline deposits: implications for the earliest agriculture in Britain and Ireland. *Journal of Archaeological Science* 11, 71-80.

Edwards, K.J. and Hirons, K.R., 1990. Environmental analyses of samples from Trench AM and a blanket peat remnant, Farm Fields excavations, Kinloch, Isle of Rhum. In Wickham-Jones, C.R. (ed.), *Rhum: Mesolithic and later sites at Kinloch, Excavations 1984-1986,* Society of Antiquaries of Scotland Monograph Series 7.

Edwards, K.J., Hirons, K.R. and Newell, P.J., 1991, The palaeoecological and prehistoric context of minerogenic layers in blanket peat: a study from Loch Dee, southwest Scotland. *The Holocene* 1, 29 - 39.

Edwards, K.J. and McIntosh, C.J., 1988. Improving the detection rate of Cereal-type pollen grains from *Ulmus* decline and earlier deposits from Scotland. *Pollen et Spores* 30, 179-188.

Edwards, K.J. and Mithen, S., 1995. The colonization of the Hebridean Islands of Western Scotland: evidence from the palynological and archaeological records. *World Archaeology* Vol. 26, 348-365.

Edwards, K.J. and Ralston, I., 1984. Post-glacial hunter-gatherers and vegetational history in Scotland. *Proceedings of the Society of Antiquaries of Scotland*, 114, 15-34.

Edwards, K.J. and Thompson, 1984. Magnetic, palynological and radiocarbon correlation and dating comparisons in long cores from a northern Irish lake. *Catena* 11, 83-89.

Edwards, K.J. and Whittington, G., 1993. Aspects of the Environmental and Depositional History of a Rock Basin Lake in Eastern Scotland, UK. In McManus, J. and Duck, R.W. (eds.), *Geomorphology and Sedimentology of lakes and reservoirs.* Chichester: John Wiley and Sons.

Edwards, K.J. and Whittington, G., 1994. Lateglacial pollen sites in the Western Isles of Scotland. *Scottish Geographical Magazine* 110, 33-39.

Edwards, K.J. and Whittington, G. 1997a. Vegetation Change. In Edwards, K.J. and Ralston, I.B.M., *Scotland: Environment and Archaeology, 8000 BC - AD 1000.* Chichester: John Wiley and Sons, 63 - 82.

Edwards, K.J. and Whittington, G., 1997b. Vegetation History and Archaeobotany.

Edwards, K.J. and Whittington, G., in press. Multiple charcoal profiles in a Scottish lake: taphonomy, fire ecology, human impact and inference. *Palaeogeography, Palaeoclimatology, Palaeoecology.*

Edwards, K.J., Whittington, G. and Hirons, K.R., 1995. The relationship between fire and long-term wet heath development in South Uist, Outer Hebrides, Scotland. In Thompson, D.B.A., Hester, A.J. and Usher, M.B. (eds.), *Heaths and Moorland: Cultural Landscapes.* Edinburgh: HMSO, 240-248.

Edwards, K.J., Whittington, G. and Tipping, R., in press. The incidence of microscopic charcoal in Lateglacial deposits. *Palaeogeography, Palaeoclimatology, Palaeoecology.*

Emeleus, C.H., 1987. The Rhum Volcano in Clutton-Brock, T.H. and Ball, M.E., *Rhum: The Natural History of an Island.* Edinburgh: Edinburgh University Press.

Emeleus, C.H., 1991. Tertiary Igneous Activity in Craig, G.Y. (ed.), *Geology of Scotland* 3rd edn., London: The Geological Society.

Faegri, K. and Iversen, J.,1989. *Textbook of Pollen Analysis*, 4th edn. (revised by K.Faegri, P.E. Kaland and K. Krzywinski). Chichester: John Wiley and Sons.

Fall, P.L., 1987. Pollen taphonomy in a canyon stream. *Quaternary Research* 28, 393-406.

Finlayson, B., 1995. Complexity in the Mesolithic of the Western Scottish Seaboard. In Fischer, A. (ed.), *Man and Sea in the Mesolithic.* Oxford: Oxbow Monograph 53.

Finlayson, B., 1996. The Transition to Agriculture 2: The Basis for Change. In Pollard, T. and Morrison, A., *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 213-224.

Finlayson, B. and Edwards, K.J., 1997. The Mesolithic. In Edwards, K.J. and Ralston, I. B. M., *Scotland: Environment and Archaeology 8000 BC - AD 1000.* Chichester: John Wiley and Sons, 109-126.

Flenley, J.R. and Pearson, M.C., 1967. Pollen analysis of a peat from the island of Canna (Inner Hebrides). *New Phytologist* 66, 299-306.

Fossitt, J.A., 1996. Late Quaternary vegetation history of the Western Isles of Scotland. *New Phytologist* 132, 171-196.

Gacia, E. and Ballesteros, E., 1994. Production of *Isoetes lacustris* in a Pyrmean lake: seasonality and ecological factors involved in the growing period. *Aquatic Botany*, 48, 77-89.

Garavell, D, 1998. Stone Age cherry tree find set to rewrite history books. *Scotland on Sunday*, 25/10/98.

Garbett, D., 1981. The Elm Decline: the depletion of a resource. *New Phytologist* 88, 573-585.

Gear, A.J. and Huntley, B., 1991. Rapid changes in the range limits of Scots pine 4000 years ago. *Science* 251, 544-547.

Girling, M. A. and Greig, J., 1985. A first fossil record for Scolytus scolytus (F.) (elm bark beetle): its occurrence in elm decline deposits from London and the implications for Neolithic elm disease. *Journal of Archaeological Science* 12, 347-351.

Grace, J., 1987. Climatic tolerance and the distribution of plants. In Rorison, I.H., Grime, J.P., Hunt, R., Hendry, G.A.F. and Lewis, D.H. (eds.), *Frontiers of Comparitive Plant Ecology.* (Reprint of New Phytologist 106 [Supplement], 1987). London: Academic Press.

Gray, J.M. and Lowe, J.J., (eds.), 1977. *Studies in the Scottish Lateglacial Environment.* Oxford: Pergamon.

Green, D.G., 1982. Fire and stability in the postglacial forests of southwest Nova Scotia. *Journal of Biogeography*, 9, 29-40.

Green, D.G., 1983. The Ecological Interpretation of Fine Resolution Pollen Records. *New Phytologist* 94, 459-477.

Green, F.H.W. and Harding, R.J., 1983. Climate of the Inner Hebrides. *Proceedings of the Royal Society of Edinburgh* 83B, 121-140.

Grigson, C. and Mellars, P., 1987. The Mammalian Remains from the Middens. Mellars, P., *Excavations on Oronsay*. Edinburgh: Edinburgh University Press.

Grime, J.P., Hodgson, J.G. and Hunt, R., 1988. *Comparitive Plant Ecology*. London, Unwin Hyman.

Groenman-van Waateringe, W., 1983. The early agricultural utilization of the Irish Landscape: the last word on the elm decline? In Reeves-Smythe, T. and Hamond. F., *Landscape Archaeology in Ireland,* B.A.R. British Series 116, 217-232.

Haggart, B.A. and Sutherland, D.G., 1992. Moine Mhor. In Walker, M.J.C., Gray, J.M. and Loe, J.J., (eds.), *The south-west Scottish Highlands: Field Guide.* Cambridge: Quaternary Research Association.

Hakenson, L. and Jansson, M., 1983. *Lake Sedimentology*. Berlin: Springer-Verlag.

Hall, V.A., 1988. The Role of Harvesting Techniques in the Dispersal of Pollen Grains of Cerealia. *Pollen et Spores* 30, 265-270.

Hall, V.A., 1989. A study of the modern pollen rain from a reconstructed 19th century farm. *Irish Naturalists' Journal.*

Harland, R., 1989. A dinoflagellate cyst record fror the last 0.7 Ma from the Rockall Plateau, northeast Atlantic Ocean. *Journal of the Geological Society*, London, 146, 945-951.

Harland, R., 1998. *Dinoflagellate Cyst Analysis of Suspected Marine Sediments from Two Sites on the Island of Ulva, North West Scotland.* Report RH/98/02/01. Unpublished.

Havinga, A.J., 1964. Investigation into the differential corrosion susceptibility of pollen and spores. *Pollen et Spores* 6, 621-635.

Henshall, A.S., 1972. *The Chambered Tombs of Scotland*, vol. 2. Edinburgh: Edinburgh University Press.

Hicks, S., 1988. The representation of different farming practices in pollen diagrams from northern Finland. In Birks, H.H., Birks, H.J.B., Karland, P.E. and Moe, D.(eds.), *The Cultural Landscape: Past Present and Future.* Cambridge: Cambridge University Press, 189-207.

Hill, M.O., 1979. *DECORANA - a FORTRAN program for Detrended Correspondance Analysis and Reciprocal Averaging.* Ithaca: Cornell University.

Hirons, K.R. and Edwards, K.J., 1990. Pollen and related studies at Kinloch, Isle of Rhum, Scotland, with particular reference to possible early human impacts on vegetation. *New Phytologist* 116, 715 - 727.

Hobbs, R.J. and Gimingham, C.H., 1987. Vegetation, fire and herbivore interactions in heathland. *Advances in Ecological Research* 16, 87-173.

Holloway, R.G., 1989. Experimental mechanical pollen degradation and its application to Quaternary age deposits. *Texas Journal of Science* 41, 131-145.

Howard, J. and Jones, A., 1990. *The Isle of Ulva: A Visitors Guide.* Ulva: Howard and Jones.

Hudson, G. and Henderson, D.J., 1983. Soils of the Inner Hebrides. *Proceedings of the Royal Society of Edinburgh* 83B; 107-120.

Hulme, P.D. and Shirriffs, J., 1994. The Late-glacial and Holocene vegetation of the Lang Lochs Mire area, Gulberwick, Shetland: a pollen and macrofossil investigation. *New Phytologist* 128, 793-806.

Huntley, B., 1993. Rapid early-Holocene migration and high abundance of hazel (*Corylus avellana* L.) alternative hypotheses. In Chambers, F.M., *Climate Change and Human Impact on the Landscape.* London, Chapman and Hall, 205-216.

Huntley, B. and Birks, H.J.B., 1983. *An Atlas of Past and Present Pollen Maps for Europe: 0-13000 years ago.* Cambridge: Cambridge University Press.

Huntley, B., Bartlein, P.J. and Prentice, I.C., 1989. Climatic control of the distribution and abundance of beech (*Fagus* L.) in Europe and North America. *Journal of Biogeography* 16, 551-560.

Jackson, S.T., 1994. Pollen and Spores in Quaternary lake sediments as sensors of vegetation composition: theoretical models and empirical evidence. In Traverse, A.(ed.), *Sedimentation of Organic Particles.* Cambridge: Cambridge University Press, 253-285.

Jacobi, R.M., Tallis, J.H. and Mellars, P.A., 1976. The southern Pennine Mesolithic and the ecological record. *Journal of Archaeological Science* 3, 307-320.

Jacobson, G.L. and Bradshaw, R.H.W., 1981. The selection of sites for palaeovegetational studies. *Quaternary Research* 16, 80-96.

Jannssen, C.R., 1973. Local and regional pollen deposition. In Birks, H.J.B. and West, R.G., *Quaternary Plant Ecology*. Oxford: Blackwell Scientific Publications, 31-42.

Jannssen, C.R., 1984. Modern pollen assemblages and vegetation in the Myrtle Lake peatland, Minnesota. *Ecological Monographs*, 54, 213-252.

Jardine, W.G., 1975. Chronology of Holocene marine transgression and regression in south-western Scotland. *Boreas* 4, 173-195.

Jermy, A.C., 1978. Climate, 6.1- 6.11. Jermy, A.C. and Crabbe, J.A. (eds.), *The Island of Mull: a survey of its flora and environment.* London: British Museum (Natural History).

Jermy, A.C. and Crabbe, J.A. (eds.), 1978. *The Island of Mull: a survey of its flora and environment.* London: British Museum (Natural History).

Jermy, A.C., James, P.W. and Eddy, A., 1978. Terrestrial Ecosystems, 10.1-10.77. Jermy, A.C. and Crabbe, J.A. (eds.), *The Island of Mull: a survey of its flora and environment.* London: British Museum (Natural History).

Jones, R.L., 1978. Late-Quaternary vegetational hostory of the North York Moors. VI. The Cleveland Moors. *Journal of Biogeography*, 5, 81-92.

Jowsey, P.C., 1966. An improved peat sampler. *New Phytologist* 65, 35-55.

Kaminski, J., 1994. Charred plant remains from Bolsay Farm. In Mithen, S.J. (ed.), *The Southern Hebrides Mesolithic Project 1994 (7th) Interim Report.* Dept. of Archaeology, University of Reading: 91-94.

Kohler, E. and Lange, E., 1979. A contribution to distinguishing cereal from wild grass pollen grains by LM and SEM. *Grana*, 18, 133 - 140.

Kvamme, K.L. and Jochim, M.A., 1985. The Environmental Basis of Mesolithic Settlement. Bonsall, C. (ed.), *The Mesolithic in Europe.* Edinburgh; John Donald Publishers Ltd., 1-12.

Lacaille, A.D., 1954. *The Stone Age in Scotland.* London: Oxford University Press.

Lang, G., 1992. Some aspects of European late- and post-glacial flora history. *Acta Botanici Fennici*, 144, 1-17.

Larsen, C.P.S., 1996. Fire and climate dynamics in the boreal forest of northern Alberta, Canada, from AD 1850 to 1989. *The Holocene* 6, 449 - 456.

Lawson, T.J. and Bonsall, C., 1986. The Palaeolithic of Scotland: a reconsideration of evidence from Reindeer Cave, Assynt. In Colcutt, S.N. (ed.), *The Palaeolithic of Britain and its Nearest Neighbours: Recent Trends.* Sheffield: Dept. of Archaeology and Prehistory University of Sheffield, 85-89.

Legg, C.J., Maltby, E. and Procter, M.C.F., 1992. The ecology of severe moorland fire on the North York Moors: seed distribution and seedling establishment of *Calluna vulgaris. Journal of Ecology* 80, 737-752.

Lehtonen, H. and Huttunen, P., 1997. History of forest fires in eastern Finland from the fifteenth century AD - the possible effects of slash-and-burn cultivation. *The Holocene* 7, 223-228.

Long, D., Wickham-Jones, C.R. and Ruckley, N.A., 1986. A flint artefact from the northern North Sea. In Roe., D.A. (ed.), *Studies in the Upper Palaeolithic of Britain and Northwest Europe.* BAR International Series 296, 55-62.

Lowe, J.J., 1982. Three Flandrian pollen profiles from the Teith Valley, Perthshire, Scotland. II. Analysis of deteriorated pollen. *New Phytologist* 90, 371-385.

Lowe, J.J., 1993. Isolating the climatic factors in early- and mid-Holocene palaeobotanical records from Scotland. In Chambers, F.M. (ed.), *Climate Change and Human Impact on the Landscape.* London, Chapman and Hall, 67-82.

Lowe, J.J. and Walker, M.J.C., 1986a. Flandrian Environmental History of the Isle of Mull, Scotland. II, Pollen Analytical Data from sites in western and northern Mull. *New Phytologist* 103, 417-436.

Lowe, J.J. and Walker, M.J.C., 1986b. Lateglacial and early Flandrian environmental hisstory of the Isle of Mull, Inner Hebrides, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 77, 1-20.

Mayewski, P.A., Buckland, P.C., Edwards, K.J., Meeker, L.D. and O'Brien, S., 1996. Climate Change Events as Seen in the Greenland Ice Core (GISP2): Implications for the Mesolithic of Scotland. In Pollard, T. and Morrison, A., (eds.), *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 74 - 86.

McCann, S.B. and Richards, A., 1969. The coastal features of the island of Rhum in the Inner Hebrides. *Scottish Journal of Geology* 5, 15-25.

McCullagh, R., 1990. Excavation at Newton, Islay. *Glasgow Archaeological Journal*, 15, (1988-1989), 23-50.

McVean, D.N., 1956a. Ecology of *Alnus glutinosa* (L.) Gaertn. V Notes on some British alder populations. *Journal of Ecology* 44, 321 - 330.

McVean, D.N., 1956b. Ecology of *Alnus glutinosa* (L.) Gaertn. VI Post-glacial history. *Journal of Ecology* 44, 331-333.

Maenza-Gmelch, T.E., 1997. Holocene vegetaion ,climate, and fire history of the Hudson Highlands, southeastern New York, USA. *The Holocene* 7, 25-37.

Mellars, P.A., 1987. *Excavations on Oronsay: Prehistoric Human Ecology on a Small Island.* Edinburgh: Edinburgh University Press.

Mercer, J., 1970. Flint tools from the present tidal zone, Lussa Bay, Isle of Jura, Argyll. *Proceedings of the Society of Antiquaries of Scotland* 102, 1-30.

Mercer, J., 1978. Lussa Wood 1: the Late-Glacial and Early Post-Glacial Occupation of Jura. *Proceedings of the Socoety of Antiquaries of Scotland*, 110, 1-32.

Mercer, J., 1974. Glenbatrick Waterhole, a microlithic site on the Isle of Jura. *Proceedings of the Prehistoric Society*, 105, 9-32.

Mithen, S., 1995. Mesolithic settlement and raw material availablitiy in the southern Hebrides. In Fischer, A. (ed.), *Man and Sea in the Mesolithic.* Oxford: Oxbow Monograph 53.

Mithen, S., 1996. *The Southern Hebrides Mesolithic Project, 1996 Progress Report.* Unpublished.

Mithen, S.J. and Lake, M., 1996. The Southern Hebrides Mesolithic Project: Reconstructing Mesolithic Settlement in Western Scotland. In Pollard, T. and Morrison, A., (eds.), *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 123-151.

Moffatt, B., 1990. Report on pollen and ancillary analyses in support of the excavations at Kinloch, Rhum, 1984, 1985, 1986. In Wickham-Jones, C.R. (ed.), *Rhum: Mesolithic and later sites at Kinloch, Excavations 1984-1986,* Society of Antiquaries of Scotland Monograph Series 7.

Moore, J., 1996. Damp Squib: How to Fire a Major Deciduous Forest in an Inclement Climate. In Pollard, T. and Morrison, A. (eds.), *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 62-73.

Moore, P.D., 1977. Stratigraphy and pollen analysis of Claish Moss, North-west Scotland: significance for the origin of surface-pools and forest history. *Journal of Ecology* 65, 375-397.

Moore, P.D., 1986. Hydrological changes in mires. In Berglund, B.E. (ed.*), Handbook of Holocene Palaeoecology and Palaeohydrology.* John Wiley and Sons: Chichester.

Moore, P.D., Webb, J.A., and Collinson, M.E., 1991. *Pollen Analysis.* Oxford, Blackwell Scientific Publications.

Morrison, A., 1996. The northward march of Palaeolithic man in Britain. In Pollard, T. and Morrison, A. (eds.), *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press.

Morrison, A. and Bonsall, C., 1989. The Early Post-Glacial Settlement of Scotland: a Review. Bonsall, C., *The Mesolithic in Europe.* Edinburgh: John Donald Publishers Ltd.

Movius, H.L., 1940. *The Irish Stone Age: It's Chronology, Development and Relations.* Cambridge: Cambridge University Press.

Mulder, Y., 1999. *Aspects of Vegetation and Settlement history in the Outer Hebrides, Scotland.* Unpublished Phd thesis, University of Sheffield.

Murray, N.A., Bonsall, C., Sutherland, D.G., Lawson, T.J. and Kitchener, A.C., 1993. Further radiocarbon determinations on reindeer remains of Middle and Late Devensian age from the Creag nan Uamh caves, Assynt, NW Scotland. *Quaternary Newsletter* 70, 1-10.

Myers, A.M., 1988. Scotland inside and outside of the British mainland Mesolithic. *Scottish Archaeological Review* No. 5, 23-39.

Newell, P.J., 1988. A buried wall in peatland by Shesader, Isle of Lewis. *Society of Antiquaries of Scotland* 118 (1988), 79-93.

Nichols, H., 1967. VI. Vegetational change, Shoreline displacement and the Human Factor in the Late Quaternary History of South-West Scotland. *Transactions of the Royal Society of Edinburgh* 67, 145-185.

O'Connell, M., 1986. Reconstruction of local landscape development in the Post-Atlantic based on palaeoecological investigations at Carrownaglogh prehistoric field system, County Mayo, Ireland. *Review of Palaeobotany and Palynology* 49, 117-126.

O'Connell, M., 1987. Early Cereal-Type pollen records from Connemara, Western Ireland and their possible significance. *Pollen et Spores* 29, 207-224.

O'Connell, M., Molly, K. and Bowler, M., 1988. Post-glacial Landscape Evolution in Connemara, Western Ireland with particular reference to woodland history. In Birks, H.H., Birks, H.J.B., Karland, P.E. and Moe, D.(eds.), *The Cultural Landscape: Past Present and Future.* Cambridge: Cambridge University.Press, 267-287.

Ogilivie, M., 1995. *The Wild Flowers of Islay.* Islay Natural History Trust.

Page, C.N., 1997. *The Ferns of Britain and Ireland.* Cambridge: Cambridge University Press.

Parish, R., 1990. A Palynological Analysis of a peat core from the Kinloch Glen, Isle of Rhum. In Wickham-Jones, C.R. (ed.), *Rhum: Mesolithic and later sites at Kinloch, Excavations 1984-1986,* Society of Antiquaries of Scotland Monograph Series 7.

Patterson, W.A. III, 1978. *The effects of past and current land disturbance on Squaw Lake, Minnesota and its watershed.* Unpublished PhD thesis, University of Minnesota, Minneapolis.

Patterson III, W.A. and Backman, A.S., 1988. Fire and disease history of forests. In Huntley, B. and Webb, T.III (eds.), *Vegetation History.* Dortrecht, Kluwer Academic Publishers, 603-632.

Patterson III, W.A., Edwards, K.J. and Maguire, D.J., 1987. Microscopic Charcoal as a Fossil Indicator of Fire. In *Quaternary Science Reviews* 6, 3-23.

Peacock, J.D., 1983. Quaternary Geology of the Inner Hebrides. In *Proceedings of the Royal Society of Edinburgh* 83B, 83-90.

Pennington, W., 1947. Studies of the Post-glacial history of British Vegetation VII. Lake Sediments: Pollen diagrams from the bottom deposits of the North basin of Lake Windermere. In *Philosophical Transactions of the Royal Society of London*, 233 B596, 137-175.

Pennington, W., 1973. Absolute pollen frequecies in the sediments of lakes of different morphometry. In Birks, H.J.B. and West, R.G., *Quaternary Plant Ecology.* Oxford: Blackwell Scientific Publications, 79-104.

Pennington, W., 1979. The origin of pollen in lake sediments: an enclosed lake compared with one receiving inflow streams. *New Phytologist* 83, 189-213.

Pennington, W., Haworth, E.Y., Bonny, A. and Lishman, J.P., 1972. Lake Sediments in Northern Scotland. In *Philosophical Transactions of the Royal Society of London Series B,* 264 B.861, 191-295.

Pilcher, J.R., Smith, A.G., Pearson, G.W. and Crowder, A., 1971. Land clearance in the Irish Neolithic: new evidence and interpretation. *Science* 172, 7/5/71, 560-562.

Prentice, I.C., 1988. Records of Vegetation in time and space: the principles of pollen analysis. In Huntley, B. and Webb, T. III. (eds.), *Vegetation History.* Dortrecht: Kluwer Academic Press, 17-42.

Price, R.J., 1983. *Scotland's Environment during the last 30,000 years.* Edinburgh: Scottish Academic Press.

Rhodes, A.N., Rumsby, B.T. and Macklin, M.G., 1992. Gallanach Beg, Oban. In Walker, M.J.C., Gray, J.M. and Loe, J.J., (eds.), *The south-west Scottish Highlands: Field Guide.* Cambridge: Quaternary Research Association, 121-125.

Rhum Reserve Office, 1996. *Woodland Restoration on Rhum*, Factsheet, Isle of Rhum National Nature Reserve.

Ritchie, J.C., Cwynar, L.C. and Spear, R.W., 1983. Evidence from north west Canada for an early Holocene Milankovitch thermal maximum. *Nature* 305, 126-128.

Ritchie, G. and Harman, M., 1996. Argyll and the Western Isles. Edinburgh: HMSO.

Robins, P, 1998, A new flint assemblage fron Cnoc Dubh, Dervaig, Mull NM 4092 5311. *Historic Argyll*, Lorn Archaeological and Historical Society, 3,15.

Robinson, D., 1983. Possible Mesolithic activity in the west of Arran: evidence from peat deposits. *Glasgow Archaeological Journal*, 10, 1-6.

Robinson, D., 1984. The estimation of the charcoal content of sediments: a comparison of methods on peat sections from the Island of Arran. In *Circaea* 2.

Robinson, D.E. and Dickson, J.H., 1988. Vegetational history and land use: a radio-carbon dated pollen diagram from Machrie Moor, Arran, Scotland. *New Phytologist* 109, 223-251.

Rorslett, B. and Johansen, S.W., 1995. Dynamic response of the submerged macrophyte, *Isoetes lacustris*, to alternating light levels under field conditions. *Aquatic Botany* 51, 223-242.

Rowley, K.R., Rowley, A. and Skvarla, J.J., 1990, Corroded exines from Havinga's Leaf Mold Experiment. *Palynology* 14, 73 - 79.

Rummery, T.A., 1983. The use of magnetic measurements in interpreting the fire histories of lakes. In *Hydrobiologia 103*, 53 - 58.

Russell, N.J., Bonsall, C. and Sutherland, D.G., 1995. The exploitation of marine molluscs in the Mesolithic of western Scotland: evidence from Ulva Cave, Inner Hebrides.In Fischer, A. (ed.), *Man and Sea in the Mesolithic.* Oxford: Oxbow Monograph 53.

Rymer, L., 1977. A Late-glacial and early post-glacial pollen diagram from Drimnagall, North Knapdale, Argyllshire. *New Phytologist*, 79, 211-221.

SAN, 1998. The earliest site in Scotland? *Scottish Archaeological News* 28, 1.

Sangster, A.G. and Dale, H.M., 1961. A preliminary study of differential pollen grain preservation. *Canadian Journal of Botany* 39, 35 - 43.

Sangster, A.G. and Dale, H.M., 1964, Pollen grains preservation of underrepresented species in fossil spectra. *Canadian Journal of Botany* 42, 437 - 449.

Saville, A., 1996. Lacaille, Microliths and the Mesolithic of Orkney. In Pollard, T. and Morrison, A., The Early Prehistory of Scotland. Edinburgh: Edinburgh University Press, 213-224.

Saville, A., 1998. Studying the Mesolithic period of Scotland: A bibliographic gazeteer. In Ashton, N., Healy, F. and Pettitt, P. (eds.), *Stone Age Archaeology: Essays in honour of John Wymer.* Oxford Monograph 102/Lithic Studies Society Occasional Paper 6.

Scaife, R., 1986. The Elm Decline in the pollen record of south east England and its relationship to early agriculture. In Jones, M. (ed.), *Archaeology and Flora of the British Isles.* Oxford: Oxford University Committee for Archaeology.

Simmons, I.G. and Innes, J.B., 1981. Tree remains in a North York Moors peat profiles. *Nature* 294, 5/11/81, 76-78.

Simmons, I.G. and Innes, J.B., 1987, Mid-Holocene adaptations and later Mesolithic forest disturbance in northern England. *Journal of Archaeological Science* 14, 385-403.

Simmons, I.G. and Innes, J.B., 1988. Late Quaternary vegetational history of the North York Moors VIII. Correlation of Flandrian II litho- and pollen stratigraphy at North Gill, Glaisdale Moor. *Journal of Biogeography* 15, 249-272.

Simmons, I.G. and Innes, J.B., 1988. Late Quaternary vegetational history of the North York Moors IX. Numerical analysis and pollen concentration analysis of Flandrian II peat profiles from North Gill, Glaisdale Moor. *Journal of Biogeography* 15, 273-297.

Simmons, I.G. and Tooley, M.J., (eds.), 1981. *The Environment in British Prehistory.* London: Duckworth.

Smith, A.G., 1970. The influence of Mesolithic and Neolithic man on British Vegetation. In Walker, D. and West, R.G., (eds.), *Studies in the Vegetational History of the British Isles.* London: Cambridge University Press, 81-96.

Smith, A.G., 1984. Newferry and the Boreal-Atlantic transition. *New Phytologist* 98, 35-55.

Smith, A.G. and Cloutman, E.W., 1988. Reconstruction of Holcene vegetation history in three-dimensions at Waun-Fignen-Felen, an upland site in South Wales. *Philosophical Transactions of the Royal Society of London Series B,* 322, 159-210.

Stace, C., 1991. *New Flora of the British Isles.* Cambridge: Cambridge University Press.

Stevenson, A.C. and Birks, H.J.B., 1995. Heaths and Moorland: Long-term ecological changes, and interactions with climate and people. In Thompson, D.B.A., Hester, A.J. and Usher, M.B. (eds.), *Heaths and Moorland: Cultural Landscapes.* Edinburgh: HMSO, 224-239.

Stewart, D.A., Walker, A. and Dickson, J.H., 1984. Pollen diagrams from Dubh Lochan, near Loch Lomond. *New Phytologist* 98, 531-549.

Stockmarr, J., 1971. Tablets with spores used in absolute pollen analysis. *Pollen et Spores* 13, 615-621.

Stuiver and Reimer, 1993. Extended 14C database and revised CALIB3.0 14C age calibration program. *Radiocarbon* 35, 215-230.

Sugden, H. and Edwards, K.J., in press. The early Holocene vegetational history of Loch a'Bhogaidh, southern Rhinns, Islay, with special reference to hazel (*Corylus avellana* L.). In Mithen, S. (ed.), *Hunter-gatherer landscape archaeology: the Southern Hebrides Mesolithic Project, 1988 - 1998.* Cambridge: McDonald Institute for Archaeological Research.

Swain, A.A., 1973. Lake Sediment History of Fire. *Quaternary Research* 3, 390-396.

Szmeja, J., 1994. Effect of disturbances ond interspecific competition in isoetid populations. *Aquatic Botany* 48, 225-238.

Tallantire, P.A., 1992. The alder (*Alnus glutinosa* (L.) Gaertn.) problem in the British Isles: a third approach to its palaeohistory. *New Phytologist* 222, 717-731.

Tinsley, H.M. and Smith, R.T., 1974. Surface pollen studies across a woodland/heath transition and their application to the interpretation of pollen diagrams. *New Phytologist* 73, 547-565.

Tipping, R., 1984. *Late Devensian - early Flandrian vegetational history and deglacial chronology of Western Argyll.* Unpublished: Phd thesis. City of London Polytechnic.

Tipping, R., 1987. The origins of corroded pollen grains at five early postglacial pollen sites in western Scotland. *Review of Palaeobotany and Palynology* 53, 151-161.

Tipping, R., 1992. Pulpit Hill, Oban. In Walker, M.J.C., Gray, J.M. and Lowe, J.J. (eds.), *The South-west Scottish Highlands: Field Guide.* Cambridge: Quaternary Research Association.

Tipping, R., 1994. The Form and Fate of Scotlands Woodlands. *Proceedings of the Society of Antiquaries of Scotland* 124, 1-54.

Tipping, R., 1996. Microscopic Charcoal Records, Inferred Human Activity and Climate Change in the Mesolithic of Northernmost Scotland. In Pollard, T. and Morrison, A., (eds.), *The Early Prehistory of Scotland.* Edinburgh: Edinburgh University Press, 39-61.

Tolonen, M.,1980. Degradation Analysis of pollen in sediments of Lake Lamminjärvi, S. Finland. *Annales Botanici Fennici* 17, 11-14.

Turner, J., 1974. Pollen diagrams from Cross Fell and their implications for former tree lines. In Haworth, E.Y. and Lund, J.W.G. (eds.), *Lake Sediments and Environmental History.* Leicester University Press.

Turner, J., 1975. The evidence for land use by prehistoric farming communities: the use of three-dimensional pollen diagrams. In Evans, J.G., Limbrey, S. and Cleere, H. (eds.), *The effect of man on the landscape: the Highland Zone.* CBA Research Report No. 11.

Turner, J., 1982. The evidence for land use by preshistoric farming communities: the use of three-dimensional pollen diagrams. In Hands, A.R. and Walker, D.R., *Archaeological Aspects of Woodland Ecology.* BAR Report S146, 86-95.

Turner, J., Innes, J.B., and Simmons, I.G., 1993. Spatial diversity in the mid-Flandrian vegetation history of North Gill, North Yorkshire. In *New Phytologist*, 123, 599-647.

Vasari, Y., 1977. Radiocarbon dating of the Lateglacial and early Flandrian vegetational succession in the Scottish Highlands and the Isle of Skye. In Gray, J.M. and Lowe, J.J. (eds.), *Studies in the Scottish Lateglacial Environment.* Oxford: Pergamon Press, 143 - 162.

Vasari, Y. and Vasari, A., 1968. Late- and post-glacial macrophytic vegetation in the lochs of northern Scotland. *Acta Botanica Fennica* 80, 1-120.

Vuorela, I., 1973. Relative pollen rain around cultivated fields. In *Acta Botanica Fennica* 102, 1-27.

Vuorela, I., 1980. Microspores of *Isoetes* as indicators of human settlement in pollen analysis. *Memoranda Societas pro fauna et flora Fennica* 56, 13-19.

Walker, M.J.C., 1984. A pollen diagram from St. Kilda, Outer Hebrides, Scotland. *New Phytologist,* 97, 99-113.

Walker, M.J.C. and Lowe, J.J., 1977. Postglacial environmental history of Rannoch Moor, Scotland, I. Three pollen diagrams from the Kinghouse area. *Journal of Biogeography* 4, 333-351.

Walker, M.J.C. and Lowe, J.J., 1979. Postglacial environmental history of Rannoch Moor, Scotland, II. Pollen diagrams and radiocarbon dates from the Rannoch Station and Corrour areas. *Journal of Biogeography* 6, 349-362.

Walker, M.J.C. and Lowe, J.J., 1981. Postglacial environmental history of Rannoch Moor, Scotland III. Early- and Mid-Flandrian pollen stratigraphic data from sites on western Rannoch Moor and near Fort William. Journal of Biogeography 8, 475-491.

Walker, M.J.C. and Lowe, J.J., 1985. Flandrian Environmental History of the Isle of Mull, Scotland. I. Pollen-stratigraphic evidence and radiocarbon dates from Glen More, south-central Mull. In *New Phytologist* 99, 587-610.

Walker, M.J.C. and Lowe, J.J., 1987. Flandrian Environmental History of the Isle of Mull, Scotland. III. A high resolution profile from Gribun, western Mull. *New Phytologist* 106, 333-347.

Walker, M.J.C. and Lowe, J.J., 1990. Reconstructing the environmental history of the last glacial-interglacial transition: evidence from the Isle of Skye, Inner Hebrides, Scotland. *Quaternary Science Reviews* 9, 15-49.

Walker, M.J.C. and Lowe, J., 1991a. Vegetational History of the Isle of Skye: I. The Late Devensian Lateglacial period. In Ballantyne, C.K., Benn, D.I., Lowe, J. and Walker, M.J.C., *The Quaternary of the Isle of Skye Field Guide.* Quaternary Research Association: Cambridge.

Walker, M.J.C. and Lowe, J., 1991b. Vegetational History of the Isle of Skye: II. The Flandrian. In Ballantyne, C.K., Benn, D.I., Lowe, J. and Walker, M.J.C., *The Quaternary of the Isle of Skye Field Guide.* Quaternary Research Association: Cambridge.

Walker, M.J.C., Coope, G.R. and Lowe, J.J., 1994. The Devensian (Weichselian) lateglacial palaeoenvironmental record from Gransmoor, East Yorkshire, England. *Quaternary Science Reviews* 12, 659-680.

Whitlock, C. and Millspaugh, S.H., 1996. Testing the assumptions of fire-history studies: and examination of modern charcoal accumulation in Yellowstone National Park, USA. *The Holocene* 6, 7-15.

Whittington, G. and Edwards, K.J., 1995. A Scottish broad: historical, stratigraphic and numerical studies associated with polleniferous deposits at Kilconquhar Loch. In Butlin, R.A. and Roberts, N. (eds.), *Ecological Relations in Historical Times*, The Institute of British Geographers Special Publications Series, 68-87.

Whittington, G., Edwards, K.J. and Cundill, P.R., 1991. Late- and post-glacial vegetational change at Black Loch, Fife, eastern Scotland - a multiple core approach. *New Phytologist*, 118, 147-166.

Whittington, G., Fallick, A. and Edwards, K.J., 1996. Stable oxygen isotope and pollen records from eastern Scotland and a consideration of Late-glacial and early Holocene climate change for Europe. *Journal of Quaternary Science* 11, 327-340.

Whittington, G., and Edwards, K.J., 1997. Climate Change. In Edwards, K.J. and Ralston, I., *Scotland: Environment and History 8000 BC-1000 AD*. Chichester: John Wiley and Sons, 11-22.

Wickham-Jones, C.R., 1990a. Recent work on the island of Rhum, Scotland. In Bonsall, C., (ed.), *The Mesolithic in Europe.* Edinburgh: John Donald Publishers Ltd.

Wickham-Jones, C.R., 1990b. *Rhum: Mesolithic and later sites at Kinloch, Excavations 1984-1986*, Society of Antiquaries of Scotland Monograph Series 7.

Wickham-Jones, C.R., 1994. *Scotlands First Settlers.* London; Batsford Ltd. (Historic Scotland).

Wickham-Jones, C.R. and Dalland, M., 1998. A small Mesolithic site at Fifeness, Fife, Scotland. *http://intarch.ac.uk/journal/issue5/wickham_index.html*

Wilkinson, D.M. and Huntley, B., 1988. Differential pollen preservation in a topogenous mire by High Force, Teesdale, northern England. In *Pollen et Spores* 66, 455-460.

Willemse, N.W. and Törnqvist, T.E., 1999. Holocene century-scale temperature variability from West Greenland lake records. *Geology* 27, 580-584.

Williams, W., 1977. *The Flandrian vegetational history of the Isle of Skye and the Morar Peninsula.* Unpublished PhD thesis, University of Cambridge.

Willis, K.J., Bennett, K.D., and Birks, H.J.B., 1998, Late Quaternary dynamics of pines in Europe. In Richardson, D.M. (ed.), *Ecology and Biogeography of Pinus*, 107-121.

Wiltshire, P.E.J., Edwards, K.J., and Bond, S., 1994. Microbially-derived metallic sulphide spherules, pollen and the waterlogging of archaeological sites. *Association of American Stratigraphic Palynologists* Contributions Series 29, 207-221.

Wood, G.D., Gabriel, A.M. and Lawson, J.C., 1996. Palynolgical techniques - processing and microscopy. In Jansonius, J. and McGregor, D.C. (eds.), *Palynology: principles and applications*. American Association of Stratigraphic Palynologists Foundation, Publishers Press, Salt Lake City, 1, 29-50.

Woodman, P.C., 1990. A review of the Scottish Mesolithic: a plea for normality. *Proceedings of the Society of Antiquaries of Scotland* 119 (1989), 1-32.

Woolley, A.R. and Jermy, A.C., 1978. Geology. 4.1-4.25. In Jermy, A.C. and Crabbe, J.A. (eds.), *The Island of Mull: a survey of its flora and environment*. London: British Museum (Natural History).

Wormell, P., 1970. Establishing woodland on the Isle of Rhum, *Scottish Forestry* 22, 207-220.

Zagwijn, W.H., 1994. Reconstruction of climate change during the Holocene in western and central Europe based on pollen records of indicator species. *Vegetation History and Archaobotany* 3, 65-68.