A high resolution palynological study of the Holocene vegetational development of central Holderness, eastern Yorkshire, with particular emphasis on the detection of prehistoric human activity

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Abstract

Compared to upland areas and Scotland, the Holocene vegetational history of lowland England is poorly known. This is particularly the case for the region of Holderness, eastern Yorkshire, where only a low number of poor temporal resolution pollen diagrams have been published, none of which include analysis of microscopic charcoal content. The records are also largely undated and as a result reliable correlation between sites is not possible, and the timings of the key vegetation changes recorded in the data remain unknown.

In this study, high resolution pollen and charcoal records were produced from four small (2-4 ha) infilled basins located within central Holderness. Complementary techniques of percentage loss-on-ignition and pollen preservation analysis were also employed, and a comprehensive radiocarbon-dating programme was undertaken to provide a secure chronological framework.

The palaeoecological records produced provide a high temporal resolution reconstruction of the Holocene development of central Holderness, particularly during the Early-Mid Holocene, and allow consideration of the changing roles that ecological interactions, climate, and human influence have played in determining the Holocene vegetational composition of the region. A number of significant landscape-scale disturbances of inferred anthropogenic origin were identified from *ca* 9290 BP onwards and shown to vary significantly in timing, duration and character between sites. It is proposed that this palaeoecological data can be used to supplement the poor archaeological record of the area.

Several key issues including the role of climatic instability in determining vegetational composition during the Early Holocene, the interpretation of incidences of cereal-type pollen, the use of the charcoal record as a proxy indicator of human activity, and the use of pollen preservation analysis as an interpretational tool are also considered.

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Volume 2

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Chapter 1: Introduction

1.1 Introduction to the study

The ability of palynology to complement experimental and observational community ecology by producing vegetational records covering long time periods has been recognised for a number of decades (e.g. Godwin, 1940, 1975; Huntley and Birks, 1983; Bennett, 1986; 1996a). The technique has greatly benefited ecological (and archaeological) theory by allowing the study of vegetational responses to events that are rare or slow acting, or cyclical such as long-term climatic shifts (Schoonmaker and Foster, 1991). Analysis of the pollen record has also allowed the testing of contemporary evolutionary theories (Bennett, 1990, 1996a). The information produced by such studies, along with the adaptability and relative accessibility of the technique, has resulted in a proliferation of palynological studies within the British Isles. This has produced a large database of knowledge, particularly concerning the post-Devensian vegetational development of upland landscapes. Compared to the uplands, however, there is a scarcity of palaeoecological studies from lowland areas, in particular eastern and southern England, and the Midlands (Edwards, 1998). Recent work has begun to fill this knowledge gap, primarily via palynology (e.g. Day, 1993, 1995; Peglar, 1993; Dark, 1998a, 1998b). In particular there is an increasing body of data from alluvial deposits (e.g. Brown, 1992, 1997a; Waller, 1993, 1994), however, as Edwards points out such types of record present interpretational problems.

The lowland areas of central and eastern Yorkshire contain many non-riverine wetland deposits in which preservation of organic material is exceptional (Van de Noort and Ellis, 1995, 1997) and, hence, have great potential for palaeoecological investigation. Whilst Holocene environmental histories of the peat bogs of the Humberhead Levels (Smith, 1985, in press; Whitehouse *et al.,* 1997; Boswijk, 1998; Whitehouse, 1999) and around Lake Flixton in the Vale of Pickering (e.g. Day, 1995; Dark, 1998a, 1998b) have recently been produced, there is still much to be learnt, in particular concerning the region of Holderness.

Holderness is unusual in that it represents a lowland landscape in which isolated, small water bodies and larger 'meres' were abundant throughout the Late-Glacial and for much of the Holocene. The diversity of site types and sizes, all lying within relatively similar topographical situations, means that it is possible to tailor the type of site to the research questions being investigated to an extent that is not possible in many regions. Despite this, very few studies have been carried out in the area (see section 2.3) and those that have are of low sampling resolution, essentially undated and primarily from large meres. As such, the records provide a framework of low spatial and temporal resolution, which is sub-optimal for addressing many questions (see section 1.2). There is consequently a great need for data capable of producing a detailed picture of the vegetational and wider landscape development of the area since the end of the last Ice Age. Of special interest is the potential that these records have to detect anthropogenic impacts upon the vegetational environment, particularly within the Mesolithic and Neolithic Periods (Edwards, 1979; Innes, 1990; Edwards and MacDonald, 1991).

The known archaeological record of Holderness is sparse, particularly when compared to the nearby areas of the Yorkshire Wolds, the Vale of Pickering and the North York Moors. In addition, knowledge of the prehistory of the area is based largely upon isolated flint scatters which are inherently difficult to interpret (Schofield, 1991). Whether this poor archaeological record reflects a low level of human activity in postglacial Holderness, or simply the loss of sites through destruction by agricultural activity, or burial beneath the extensive colluvial, alluvial and peat deposits that cover much of the region, remains to be discovered. The production of a series of continuous records of vegetational development would serve to complement this fragmentary archaeological record and may shed more light on the extent of prehistoric and historical human occupation of Holderness. Indeed, given the hypothesised evidence for vegetational disturbance attributable to Mesolithic peoples in both the Vale of Pickering (Cloutman, 1988; Day, 1995) and the North York Moors (e.g. Innes and Simmons, 1988; Innes, 1990), it would be interesting to see whether there is any similar evidence from Holderness.

1.2 Study Aims

1. To produce a series of well-dated, high temporal resolution records of the Holocene vegetational development around four sites in central Holderness.
2. To produce complementary records of fire regime and erosional history.
3. To use these records to reconstruct a detailed environmental history for the area and to infer the changing roles that climate, ecological interactions and both natural and human disturbance have played in controlling vegetational development through time. The records will also allow a series of questions to be addressed including:
   (i) Are the Holocene Regional Pollen Assemblage Zones proposed by Beckett (1981) and adapted by Flenley (1987) sound, or can they be refined? What are the start and end dates of the zones?
   (ii) When did the major arboreal taxa initially expand within central Holderness?
   (iii) Are any expansions or declines of taxa synchronous between sites?
   (iv) Is there any evidence for human disturbance in the vegetational record, particularly during the Mesolithic and Neolithic Periods? If so then how does any hypothesised human disturbance vary between sites in terms of its nature, timing and duration?
   (v) Can the palaeoecological records plausibly be used to supplement the archaeological record?
4. To reassess the separation of Cerealia pollen from that of wild grasses, particularly in the context of the initiation of arable farming within Holderness.
5. To look at the use of pollen preservation state as an interpretative tool.

1.3 Thesis layout

Chapter two provides a background to the geography and geology of the study area and summarises the Late-Glacial and Holocene environmental and archaeological histories of the region. The theoretical principles underlying the research strategy of the project are explained in chapter three, with detailed introductions to the study sites also given. Chapter four overviews the theoretical background and practical application of the field and laboratory techniques employed in the study. Chapter five is the first of the results sections and deals with the separation of Cerealia pollen from that of wild grasses, in the context of the detection of arable agriculture within the pollen record. The results for each site are then presented and discussed in chapters six to nine, and a synthesis of the main results of the study is given in chapter 10. This final chapter also contains an evaluation of the success of the project and recommendations for future work. Volume one contains the text and bibliography, with all Figures, Tables, Plates and Appendices contained in volume two.

1.4 Definitions and conventions

Uncalibrated radiocarbon dates are quoted as radiocarbon years before present (BP), where present is taken as 1950 AD. Calibrated radiocarbon dates are cited as cal BP or cal AD/BC, with the calibration technique described in section 4.4.7. All dates are cited along with an error quoted at 1 SD. Late-Glacial refers to the period towards the end of the last Ice Age from *ca* 14,000-10,200 BP, and the Holocene refers to the period from *ca* 10,200 BP to present and is equivalent to the postglacial or Flandrian stage. The British system is used to name glacial and interglacial periods, with the Devensian being equivalent to the European Weichselian. Dating of cultural periods primarily follows Spratt (1993a) and is based on work from the North York Moors and the Vale of Pickering. Whilst this provides a framework for discussion it is accepted that the transitions between cultural and technological periods are unlikely to have been sharp, or necessarily synchronous across the region, and as such the period start and end dates have little absolute meaning. A full list of period dates is given in Appendix 1.

Chapter 2: Geographical and geological background, and the Younger Dryas and Holocene in Holderness: environment and archaeology

2.1 Introduction

This chapter provides a background to the geography and geology of Holderness and presents a synthesis of the palaeoenvironmental and archaeological work that has been carried out in and around the study area. A summary of the geography and geology of the area is given in section 2.2. Palaeoenvironmental and archaeological backgrounds to Holderness and selected nearby areas are provided in sections 2.3 and 2.4, and the Holocene development of the North Sea Basin is summarised in section 2.5.

2.2 Geographical and geological background to the study area

2.2.1 Introduction to the study area

Holderness forms part of the former East Riding of Yorkshire and is bounded to the north and west by the Yorkshire Wolds, by the Humber Estuary to the south and by the North Sea to the east (see Figure 2.1). The present day landscape is low-lying, rising to a maximum of *ca* 35 m OD at Dimlington High Land (Figure 2.1) and consists of two main landscape types. The morainic topography of central and eastern Holderness is gently undulating and generally between 10-20 m OD. In contrast, the landscape of southern Holderness and along the valley of the River Hull (referred to as the Hull Valley in this text following Van de Noort and Davies, 1993, 2000) is almost entirely below 10 m OD and comparatively level. As the higher ground of eastern Holderness forms the main watershed, drainage is predominately inland towards the Hull Valley, with the drainage network largely consisting of natural streams that have been adapted to form artificial drains (Ellis, 1995). The climate is similar to much of eastern England with annual rainfall typically less than 700 mm and mean daily maximum January and July temperatures of 6 °C and 19 °C respectively (Meteorological Office, 1985). Arable farming is the dominant form of land use (see section 2.2.2), with the only built-up areas of note being Kingston Upon Hull, Beverley, Hedon and the coastal resorts of Withernsea and Hornsea.

Holderness is a region of considerable coastal activity, with the unconsolidated Quaternary deposits of its coastline eroding at average rates of 1-2 m per year (Ellis, 1995), increasing to 2.75 m per year towards the southernmost tip (Valentin, 1971). These rates are likely to vary considerably depending upon the beach morphology and cliff form, as well as upon the frequency of onshore storms (Pringle, 1981). This erosion has led to coastal retreat of between 3 km (Valentin, 1971) and 4 km (Sheppard, 1912) since Roman times, with 27 known settlements having been lost to the sea (Sheppard, 1912). Associated with the process of longshore drift is the formation of Spurn Point (Figure 2.1), a spit that develops cyclically, with phases of construction alternating with ones of destruction (de Boer, 1978).

2.2.2 Land use and vegetation of Holderness

Arable farming is by far the most frequent form of land use, with 85 % of the land in southern and eastern Holderness being under crops or fallow and four of the 45 parishes with published returns containing in excess of 94 % arable land (based on MAFF parish data for 1987: in Middleton, 1995). In almost all cases cereals comprise more than 60 % of the arable crop cover, with legumes, oil seed rape and sugar beet making up the remainder. The dominance of arable farming reflects the high fertility of the soils, with much of the land being of Grade 2 or 3 in quality. Grassland covers only 13 % of morainic Holderness and has been declining in importance, particularly over the past 50 years, as wetland areas continue to be drained and permanent pasture is lost (Middleton, 1995). Although scattered clumps of trees form linear shelter belts and boundary hedges, woodland is particularly scarce, with all parishes having less than 1 % woodland cover (Middleton, 1995). A considerable proportion of the hedges have been lost since the 1960s due to changing farming practice (Crackles, 1990), with the remaining hedgerows containing a total of 32 species of tree and shrub and showing strong similarity to the composition of hedges on the Yorkshire Wolds (Boatman, 1980).

Although the landscape of Holderness is characterised by open farmland containing small, scattered villages, some semi-natural vegetation communities survive. Meadow flora exist in areas of unimproved pasture in the poorly drained former carr land, and remnants of species-rich fen occur along feeder streams of the River Hull and by Hornsea Mere (Crackles, 1990). Disused railway tracks provide refuges for grassland species that are otherwise rare including the Common spotted orchid (*Dactylorhiza fuchsii*), along with grass verge and embankment communities composed of species that are disappearing from the surrounding farmland (Crackles, 1990). Significant areas of salt-marsh occur along the northern bank of the Humber Estuary, but are generally species poor, unlike the coastal area of Spurn Point which contains a diverse array of habitats (with 340 species of vascular plant having been recorded since 1945 [Crackles, 1990]).

2.2.3 Geological and geomorphological background

The extent to which the geological evolution of a landscape influences its archaeological history, whether via topography, climate, soil type or resource availability should not be underestimated (Hemingway, 1982). This section provides a brief geological background to the study area and surrounding regions.

2.2.3.1 Solid and drift geology

The solid geology of eastern Yorkshire is shown in Figure 2.2. Mesozoic deposits form the underlying bedrock throughout eastern Yorkshire and North Lincolnshire, with Upper Cretaceous chalk underlying all of Holderness (Arnett, 1990). The chalk rises significantly to the west of The Hull Valley and northeast Lincolnshire to form the Yorkshire Wolds (up to *ca* 240 m OD) and Lincolnshire Wolds (up to *ca* 100 m OD; Figure 2.1), the former comprising the northernmost chalk hills in England (Lewin, 1969). The Yorkshire Wolds form an inverted L-shape caused by gentle folding of the chalk during the Tertiary Period (Catt, 1990) and syncline gently along a northwest-southeast axis, plunging to the southeast at an angle of 2-4° (although minor local variations occur; Versey, 1948; Lewin, 1969). To the east of the Wolds the chalk continues to dip eastwards beneath an increasing thickness of Quaternary deposits, with solid chalk lying at approximately 30-35 m below OD at the present Holderness coastline (Catt, 1987). Given that most of the Vales of Pickering and York, northeast Lincolnshire and Holderness (Figure 2.1) all lie below *ca* 20 m OD, the chalk escarpments of the Yorkshire and Lincolnshire Wolds are major landscape features and are likely to have had significant influence on the archaeological histories of the areas.

The surficial geology of eastern Yorkshire is shown in Figure 2.3. With the exception of most of the Wolds and several other isolated areas, the solid geology of eastern Yorkshire is buried beneath a cover of Late Quaternary deposits, primarily laid down during the Late-Glacial and Holocene periods (see 2.2.3.2). During the Devensian maximum (*ca* 20,000 BP; Eyles *et al.*, 1994), ice sheets penetrated Holderness from the northeast (Figure 2.4) and backed up against the Yorkshire Wolds to a height of *ca* 60 m OD (Catt, 1990). The movement of these ice sheets resulted in the deposition of a series of tills across Holderness. The till deposits vary in thickness from *ca* 30 m in southeast Holderness to less than 1 m at the edge of the Wolds (Ellis, 1995) and their stratigraphy has been much debated (see Table 2.1), with the three-fold division of Madgett and Catt (1978) now being generally accepted. Patches of sand and gravel were also deposited in Holderness during the Devensian, particularly around Kelsey Hill, Brandesburton and Gransmoor (Figure 2.3). It is likely that the deposits are glaciofluvial, being deposited both beneath and in front of the Devensian ice sheet as it retreated during the Late-Glacial (Catt and Penny, 1966; Walker *et al.*, 1993; Ellis, 1995).

The deposition of these till and gravel deposits within Holderness led to the irregular relief that is still visible today (particularly in northern and central areas) and greatly influenced the development of soil types. The hummocky land surface left on ice retreat was nutrient rich and contained numerous freshwater bodies within depressions, valleys and kettleholes. Many of these former waterbodies are infilled, containing sediment sequences covering the Late-Glacial and at least part of the Holocene (Sheppard, 1957; Gilbertson, 1984a; Flenley, 1987; Dinnin and Lillie, 1995a, 1995b), and only Hornsea Mere survives as open water today.

2.2.3.2 Holocene deposits and the soils of Holderness

Rising sea-levels during the Holocene have led to the accumulation of large areas of peat and both freshwater and marine alluvium, particularly in the lower-lying areas of southern Holderness and alongside the River Hull and its tributaries (Figure 2.3). In central Holderness, significant areas of peat and alluvium occur in the low-lying Keyingham, Roos and Winestead Valleys. The deposits accumulated as a result of estuarine incursion and impeded drainage caused by rising sea-level sometime prior to *ca* 5300 BP (Dinnin and Lillie, 1995b). Significant areas of peat also occur at or close to the present-day land surface in the basins of the larger infilled meres (e.g. Lambwath Mere), and spatially restricted peats are present in a number of the smaller infilled kettleholes (Sheppard, 1957; Dinnin and Lillie, 1995a). Intense agricultural activity within Holderness has led to the deposition of colluvial sediments in many valleys and depressions. In some areas considerable thicknesses of colluvium exist, for example the organic sediments contained within Flaxmere (Barker, 1987) and Cess Dell (this volume) are capped by approximately 65 cm and 42 cm of deposit, respectively. Areas of land have also been reclaimed from the Humber Estuary since the seventeenth century (e.g. Sunk Island in southern Holderness; Phillips, 1829; Arnett, 1990), the sediments of these areas subsequently consisting of fine-grained estuarine alluvium.

As a result of peat formation and the deposition of extensive areas of colluvium and alluvium, much of the earlier Holocene landsurface of Holderness is obscured. This is likely to have important implications for the visibility of archaeological material. The combination of peat and alluvium formation in valley bottoms and millennia of soil erosion through agricultural activity is also likely to have resulted in considerable 'smoothing' of the landscape since the start of the Holocene.

The dominant soil types of Holderness are shown in Figure 2.5. The main characteristics of the soils are determined by the parent material from which they are derived and drainage conditions (Ellis, 1990). As such most of the till- and alluvium-based soils of Holderness are clay-rich with tendencies towards poor drainage, whilst those formed on glaciofluvial deposits are frequently sandy and freely draining (Ellis, 1995). Brown soils are found on the drier areas of the region such as the higher areas of morainic

Holderness and at the foot of the Wolds dipslope (Arnett, 1990). Due to the high clay content, many of the brown soils still exhibit stagnogleyic characteristics towards the surface (Ellis, 1995). Where drainage is impeded, surface-water and ground-water gleys dominate. Such soils are characterised by low biological activity and are frequent across much of Holderness. In particularly poorly draining areas such as parts of the Hull Valley, low rates of decay result in the formation of organic gleys (peaty soils), with peats occurring where waterlogging is more complete (Ellis, 2000). Peaty soils also occur in central Holderness on the surface of a number of the former meres (Ellis, 1995). Other soils present in the region include restricted areas of podzols (formed on glaciofluvial sands and gravels) and lithomorphic soils, significant expanses of the latter only being present on areas of Spurn Point (Arnett, 1990).

It is worth remembering that artificial drainage, particularly since the nineteenth century, has significantly reduced the level of the water table in Holderness, with levels presently lowered by between *ca* 1-3 m (Ellis, 1995). This is likely to have influenced soil development during the later Historical Period.

2.3 Palaeoenvironmental background

This section provides a palaeoenvironmental background to the study area. Whilst the discussion centres in detail upon Holderness, summaries of the records from the nearby areas of the Yorkshire Wolds and the Vale of Pickering are given in order to place Holderness into a regional context. The North York Moors are also discussed in the light of their archaeological importance and because of the range and depth of palaeoenvironmental studies that have been carried out in association with this archaeology. The Holocene evolution of the formerly exposed North Sea Basin is summarised separately in section 2.5. Although emphasis is placed upon the Holocene, a brief overview of the vegetational development during the Younger Dryas (cf. GS-1 event of Björck *et al.* [1998] and see Edwards *et al.* [in press]) is also given. This was done to allow the data from Sproatley Bog (chapter 8) to be placed into a wider context. The locations of the palaeoenvironmental sites mentioned in the text are shown in Figure 2.6.

2.3.1 Vegetational development during the Younger Dryas (Loch Lomond Stadial)

2.3.1.1 Holderness

Deposits spanning the latter part of the Late-Glacial Period are present in many of the infilled basins of Holderness (Dinnin and Lillie, 1995a), with palynological studies having been carried out at the sites of The Bog at Roos and Hornsea Old Mere (Beckett, 1975, 1981) and Skipsea Withow Mere (Hunt *et al.*, 1984). A detailed pollen and Coleopteran study was also carried out at Gransmoor by Walker *et al.* (1993) and forms the only published palaeoentomological material from Holderness. Limited macrobotanical (Hunt *et al.*, 1984) and molluscan (Thew *et al.*, 1984) data is available for the Late-Glacial section at Skipsea Withow Mere and extremely low resolution pollen diagrams have been produced for Sproatley Bog (Robinson, 1986), Flaxmere (Jennings, 1975) and Skipsea Bail Mere (Flenley, 1984). Late-Glacial Regional Pollen Assemblage Zones have been proposed by Flenley (1984).

Throughout the Late-Glacial and Early Holocene, Holderness formed part of a large land-mass stretching across the North Sea and joining continental Europe (see section 2.5). The Younger Dryas has been dated at The Bog at Roos as spanning the period between 11,220±220 BP (Birm-406) and 10,120±180 BP (Birm-405). The Gransmoor data suggest that during this time, summer temperatures fluctuated between 10-12°C and winter temperatures were as low as -20°C, with cold, dry easterly winds. These climatic conditions resulted in the formation of areas of permafrost (Walker *et al.*, 1993). The vegetational record is similar from all sites, with sedges and grasses dominant and tree and shrub pollen relatively sparse. *Betula* and *Pinus sylvestris* form the most frequent arboreal types, with pine reaching >30 % TLP at The Bog at Roos (Beckett, 1975), although whether this reflects local growth or long-distance transport is unclear. The herb floras are indicative of highly disturbed, skeletal ground (Walker *et al.*, 1993). At The Bog at Roos and Skipsea Withow Mere intense erosion occurred, with reworked pre-Quaternary microfossils frequent at Gransmoor. The vegetational landscape is thus likely to have been a highly open steppe or tundra, perhaps with isolated patches of *Salix, Juniperus* and *Betula.* It is probable that both dwarf and tree birches were present, with tree birch macrofossils from Skipsea Withow Mere dated to 10,710±70 BP (Q-3035) and 10,440±80 BP (SRR 1943: Hunt *et al.,* 1984).

2.3.1.2 Comparison with surrounding areas

The Younger Dryas vegetational development of Holderness is comparable with the pollen records obtained from sites elsewhere in Yorkshire, such as at Star Carr (Day, 1995; Dark, 1998b), Tadcaster (Bartley, 1962), Seamer Carr (Jones, 1976) and Kildale Hall (Jones, 1977). The climatic data fit in with the wider trends observed for the rest of northwest Europe, with evidence from the Greenland ice core (Lowe *et al.,* 1995) and temperature curves for the Younger Dryas in northwest Europe (Walker *et al.,* 1994) and Scandinavia (Lowe *et al.,* 1994) broadly correlating with the Gransmoor results.

2.3.2 Vegetational development during the Holocene

2.3.2.1 Holderness

Whilst there are more published pollen records covering the Holocene than the preceding Late-Glacial, none are securely dated and all are at relatively low temporal resolutions. Most of the records cover the Early/Mid Holocene, with only the sediments from The Bog at Roos (Beckett, 1975, 1981) approaching a full Holocene record. Other pollen diagrams are published for Gransmoor and Hornsea Old Mere (Beckett, 1975, 1981), Skipsea Withow Mere (Blackham and Flenley, 1984) and Brandesburton (Clark and Godwin, 1956). Sequences from the present day Humber foreshore are also available from North Ferriby (Buckland *et al.,* 1990) and Faxfleet (Hulme and Beckett, 1973), whilst spot samples and outline pollen profiles from southern Holderness are available in Gaunt and Tooley (1974), and Taylor (1995). Evidence for the presence of well preserved Holocene material at Sproatley Bog, Flaxmere, and Skipsea Low and Bail Meres is provided by several undergraduate projects (Flenley, 1984; Robinson, 1986; Barker, 1987). A series of Regional Pollen Assemblage Zones (RPAZ's) have been proposed by Beckett (1981) and form the basis of the following discussion. Although the major vegetational changes that mark the transitions between these zones are largely undated, tentative age ranges were assigned by Flenley (1987) on the basis of dates for similar palynological events in other areas of England. These age ranges are also given below.

1. The Early Holocene (*ca* 10,200 BP to *ca* 5000 BP)

(1) *Betula-Pinus* RPAZ (*ca* 10,200-9000 BP)

The *Betula-Pinus* RPAZ covers the period from the start of the Holocene (dated at The Bog at Roos to 10,120±180 BP; Birm-405) to the initial *Corylus avellana*-type rise. At all sites the vegetation is dominated initially by open birch woodland, with *Filipendula* contributing a large proportion of the herb pollen. At The Bog at Roos, the *Betula* pollen has been shown to be predominately from tree birch. *Juniperus, B. nana* and open ground herbs rapidly decrease in importance, suggesting the formation of a more closed canopy as the zone progresses. Pollen from *Salix* and *Pinus sylvestris* is also present, and it is possible that some of the *Pinus* pollen reflects limited local growth.

(2) *Corylus/Myrica-Ulmus* RPAZ (*ca* 9000-7000 BP)

This covers the period from the start of the *Corylus* rise until the *Alnus* rise and is completely undated in Holderness. *Corylus avellana*-type pollen dominates the pollen rain throughout with *Ulmus* and *Quercus* expanding synchronously early within the zone at Skipsea Withow Gap and Gransmoor. This is not the case at The Bog at Roos and Hornsea Old Mere where *Ulmus* seems to expand significantly earlier than *Quercus*. Whether this apparent difference in migrational order is real or an effect of sedimentation regime is impossible to say given the lack of independent dating controls. *Pinus sylvestris* pollen is sparse throughout, with low levels of herb pollen indicating an element of open ground, at least locally.

(3) *Alnus-Ulmus* RPAZ (*ca* 7000-5000 BP)

This covers the period from the *Alnus* rise until the *Ulmus* decline (the latter event dated at Gransmoor to 5099±50 BP [SR-229]). Throughout the zone, mixed deciduous woodland is suggested, with *Fraxinus* and *Tilia* expanding, and herb pollen at its lowest Holocene levels. It appears that *Tilia-Quercus-Corylus-Ulmus* woodland dominated on the till-based soils, with *Tilia* particularly frequent on the more freely draining sand- and gravel-based soils around Gransmoor and Brandesburton (Dinnin, 1995).

2. The later Holocene (*ca* 5000 BP to present)

(4) *Alnus-Quercus* RPAZ (*ca* 5000-2500 BP)

The *Alnus-Quercus* zone covers the period from the *Ulmus* decline until the first evidence of major landscape clearance. Whilst this has been tentatively dated as covering the period from *ca* 5000-2500 BP, landscape clearance is likely to have occurred at different rates and times throughout Holderness (Dinnin, 1995). Consequently the end date for this zone should be used solely as a guideline. The zone contains the first firm evidence of human impact, albeit small-scale, and hampered by the absence of charcoal quantification in any of the studies. The low levels of ruderal pollen and limited evidence of woodland recession at The Bog at Roos and Hornsea Old Mere suggest that the landscape remained essentially wooded, although a greater proportion of disturbed ground is seen at Skipsea Withow Gap. Interestingly, pollen and macrofossils of water chestnut (*Trapa natans*) were found during this zone within the complex of Skipsea Low, Bail and Withow Meres (Flenley *et al.*, 1975). Whilst it is possible that the incidences may have had an anthropogenic origin (*ibid*), it seems more likely that they reflect a natural, albeit slow, migratory response to Holocene climatic amelioration (cf. Korhola and Tikkanen, 1997).

(5) *Alnus*-Gramineae RPAZ (*ca* 2500-0 BP)

This final zone is particularly unsatisfactory, with only the sites of The Bog at Roos, Hornsea Old Mere, and Skipsea Low and Bail Meres still accreting sediment (in the latter three cases for part of the zone only). The zone opens with the first evidence of major, sustained woodland clearance and given the previous reservation that clearance is likely to have varied in both time and space across the region, the zone could be aided by more studies, presently being:

"...too ill defined to be instructive" (Dinnin, 1995, p.40).

The vegetation of the zone is characterised by declining arboreal pollen representation and increasing evidence of human activity. After an initial, apparently rapid, woodland decline a minor woodland recovery occurs at The Bog at Roos, before the record is swamped by on-site pollen as *Betula-Salix* carr invades the bog surface. If Holderness fits into the same pattern of landscape clearance as the rest of lowland eastern England, then it is likely that the opening of the zone occurs sometime within the Bronze Age (e.g. Bell and Walker, 1995; Roberts, 1995).

The pollen records discussed above have all come from sites located on the undulating land surface of eastern and northern Holderness. Whilst similar vegetation communities probably existed on the higher (drier) parts of the Hull Valley (Lillie and Gearey, 2000) and southern Holderness, the Holocene vegetational histories of the lower-lying areas are likely to have been quite different. During the earlier Holocene (prior to *ca* 8000 BP), soil conditions are likely to have been similar to those on the more poorly draining regions of the higher ground, so a vegetational development similar to that of such areas seems reasonable. However, rising sea-level caused the deposition of considerable volumes of estuarine alluvium along with extensive peat development in the lower areas, particularly along the River Hull and the valleys of the streams draining southern Holderness (e.g. around the Easington, Keyingham, Winestead, Kilnsea and Roos Drains [Dinnin and Lillie, 1995]). The record of sea-level change in the Humber Estuary is still incomplete, but it is evident that the maximum rate of Holocene sea-level rise occurred after *ca* 8000 BP (Gaunt and Tooley, 1974), with recent work suggesting that the Mean High Water of Spring Tides in the Humber rose from *ca* -9 m OD at 7500 cal BP (*ca* 6600 BP) to 0 m OD by 4000 cal BP (*ca* 4000 BP; Long *et al.*, 1998). This rising sea-level caused the formation of a salt marsh and creek system in the Keyingham and Roos valleys prior to 4000 cal BC (*ca* 5300 BP), and the accumulation of freshwater peat further up the valleys beyond the zone of direct tidal influence (Dinnin and Lillie, 1995b). A similar situation occurred along the lower reaches of the River Hull. It appears that the greatest marine influence during the Holocene was between 3000-2800 BP (Long *et al.*, 1998), with Van de Noort and Davies (1993) suggesting that estuarine conditions were widespread in the lower Hull Valley at this time. The waterlogging of former dryland sites leading to peat formation is also suggested in areas higher up the Hull Valley (Dent, 1990). Marine influence lessened after *ca* 2700-2300 BP, although peat continued to form in areas such as the Roos Valley (Dinnin and Lillie, 1995b). Place name, documentary and stratigraphic evidence suggests that considerable areas of marsh and carr existed in southern and western Holderness until drainage in the last few centuries (Sheppard, 1958, 1966; Dent, 1990), with the low-lying landscape being one of isolated drier ridges and hills amongst extensive areas of carr and estuarine habitat. Historically, salt-water has penetrated the Hull Valley as far north as Skerne on at least one occasion (Dent, 1990).

The distinction can thus be made between the higher and lower-lying areas of Holderness, with the latter likely to have been inundated, seasonally flooded or at the least poorly draining for much of the Mid-later Holocene. The vegetational development of these lower areas is likely to have been quite different as a result, with the landscape dominated by areas of *Alnus-Salix* carr, reedswamp and wet grassland. Closer to estuarine creeks, saltmarsh communities of halophytic species are likely to have dominated. These conditions would have had far-reaching implications for both resource availability, settlement pattern and land use throughout later prehistory and history.

2.3.2.2 Comparison with surrounding areas

The almost complete absence of organic deposits on the Yorkshire Wolds means that there is very little palaeoenvironmental information available for the region, the only available studies being from sites in the valleys that dissect the Wolds. Mollusca have been analysed from soils beneath burial mounds and ditches at several locations. The fauna from within Neolithic enclosure and ring ditches at Kirkburn were suggestive of a moist tall-herb community with there being no evidence for trees or shrubs in the vicinity (Thew and Wagner, 1991). Mollusca from Iron Age and Early Medieval (Anglian) contexts at Kirkburn and Garton Station indicated that the sites were surrounded by short, calcareous grassland that was probably grazed (*ibid*). It is likely that there was a nearby hedge system contemporaneous with the Iron Age deposits from Kirkburn. A permanent damp grassland fauna has also been recovered from beneath Bronze Age barrows at Garton Slack (Blackburn, 1908). At face value these results collectively indicate the presence of significant areas of open grassland in the Wolds valleys from the Neolithic onwards, however, the deposits analysed are not likely to have been indicative of the situation on the areas of the Wolds away from the valley bottoms. The soils on the valley bottoms are very thin and gravel based and are dissected by ephemeral streams ('gypseys'). Whilst trees can grow on these valley floors, rooting is very shallow, which in combination with the unstable nature of the soils means that trees and shrubs are highly susceptible to drought, flooding and windthrow (Pat Wagner, pers. comm.). It is thus likely that the valley floors may have been naturally unwooded (or sparsely wooded) for much of the Holocene, grazing perhaps helping to maintain this landscape (*sensu* Buckland and Edwards, 1984).

A single pollen diagram is available from the site of Willow Garth, a small (*ca* 5 ha) area of carr in the Great Wold Valley (Bush and Flenley, 1987; Bush, 1988, 1993). The record is dominated by pollen from *Betula, Pinus sylvestris* and Poaceae in the terminal Late-Glacial/Early Holocene, with the proportion of Poaceae rapidly declining until *ca* 8290±80 BP (SRR-268). After this period Poaceae pollen increases to a fairly constant value of *ca* 40 % TLP, with total tree pollen falling to values of <25 % TLP. It was primarily on the basis of the high level of Poaceae pollen that clearance by Mesolithic peoples was inferred (episodes from 8800-8600 BP and 8400-8250 BP in Bush and Ellis, 1987, but from 8900 BP onwards in Bush, 1988). The record has clear problems however, due to a series of hiatuses and periods of probable erosion and reworking (Pat Wagner, pers. comm). Whilst the large proportion of Poaceae pollen in the spectra is not in doubt, it seems unnecessary to invoke Mesolithic interference as the primary cause. It is more likely that the grass component reflects local input from the on-site fen community (Thomas, 1989). This is supported by Day (1995) who suggests that serious discrepancies between the pollen and macrofossil data indicate that the pollen record is heavily biased by local input. It is likely that the slopes and higher areas of the Wolds would have been wooded for at least part of the Holocene, but the only evidence that we have for this at present comes from the presence of dark forest soils on the Wolds top (Pat Wagner, pers. comm.).

A concise summary of the Holocene vegetational development of the North York Moors is provided by Simmons *et al.* (1993), and forms the basis of this discussion. A broad distinction can be made between the development of the higher and lower areas of the region. The western and northern fringes of the Moors and the lower dales initially showed an expansion of *Juniperus communis* and *Hippophaë rhamnoides*, before a canopy of tree birch and then *Corylus-Pinus* woodland rapidly established. *Quercus* and *Ulmus* colonised the fringing lowlands and *Alnus glutinosa* rapidly expanded after *ca* 7000 BP. After this period a dense mixed deciduous woodland dominated until later prehistoric or historical times. A contrasting picture is seen on the uplands and Moors, where a greater open ground element prevailed. The initial Holocene landscape was dominated by open heathland, with *Empetrum nigrum* and Poaceae important. As the early successional trees expanded, patches of *Betula* and then *Betula-Corylus* scrub formed, but open heath remained in places. It appears that prior to *ca* 8000 BP *Ulmus* and *Quercus* were only present in more sheltered sites and on the better soils. Between *ca* 8000 BP and 7000 BP the canopy became progressively more closed with areas of *Betula* then *Pinus-Corylus* woodland occurring. After *ca* 7000 BP *Alnus* expanded and the mixed deciduous component of the open woodland steadily increased. The formation of blanket peat initiated at a similar time. Some *Ulmus* existed at all altitudes, but *Tilia* never appears to have been a major component, even on the lower levels of the Moors. From *ca* 5000 BP onwards the proportion of heathland on the uplands greatly increased.

A great deal of detailed research has been aimed at investigating the effects of humans on the Moors environment throughout the Holocene, with the result that the region has become one of the most studied in England, with disturbances from the Early Mesolithic onwards having been attributed to humans. Declines in tree pollen and associated increases in the representation of open and disturbed ground taxa have been noted at a large number of sites on the Moors during the later Mesolithic (e.g. Jones, 1976; Innes, 1990; Simmons and Innes, 1996a), with Simmons *et al.* (1993) listing in excess of 20 sites showing episodes of forest recession during this period. These changes are generally associated with increases in charcoal, with thick layers having been found at Ewe Crag Slack (Jones, 1976) and North Gill (Innes, 1990; Simmons and Innes, 1996b), and have often been attributed to deliberate clearance and burning by Mesolithic peoples. Limited evidence of woodland disturbance is also seen during the Neolithic, but it is not until the Bronze Age that clearance becomes more widespread and prolonged (Simmons *et al.*, 1993). Although limited woodland regeneration occurred towards the end of the Bronze Age, the landscape remained dominated by blanket bog and heath, with woodland on the steeper slopes and in the wetter valleys. The intensity of land use and clearance extent increased again from the Iron Age onwards (e.g. Simmons and Cundill, 1974; Simmons *et al.*, 1993).

Vegetational records from the Vale of Pickering include those from Star Carr (Walker and Godwin, 1954; Cloutman and Smith, 1988; Day, 1995; Dark, 1998a, 1998b) and Seamer Carr (Cloutman, 1988). The Early-Mid Holocene vegetational development is similar to that described for Holderness, with the initial Holocene record suggestive of an open *Juniperus-Betula-Salix* scrub with plentiful *Filipendula.* This was replaced first by open *Betula-* and then *Corylus*-based woodland, with hazel expanding at Star Carr from *ca* 9000 BP (Day, 1995). It is likely that *Ulmus* expanded at a similar time with *Alnus* locally present from *ca* 7640±85 BP (OxA-4042). Although *Quercus* seems to have expanded coincident with *Alnus*, it is probable that a depositional hiatus of *ca* 600 years occurred prior to the *Alnus* expansion, and *Quercus* may have been locally present at an earlier date (Day, 1995). After this period the development of a mixed deciduous woodland is suggested, with the Star Carr record ceasing at 6515±85 BP (OxA-4041). It is likely that the Seamer Carr records cease at a similar time (Cloutman, 1988).

Whilst there is abundant evidence for potential Mesolithic clearance activity on the North York Moors, there is little indication of disturbance in the record from Star Carr coincident with the occupation of the site. Cores obtained from the lake edge close to the occupation site show increases in both microscopic and macroscopic charcoal (Dark, 1998a), although no increase in microscopic charcoal input is seen in a core obtained from the lake centre (Dark, 1998b). Most of the identifiable fragments were from *Phragmites* which suggests that local burning of the reedswamp occurred (Dark, 1998c). Further evidence of *in-situ* burning of vegetation is seen after the *Alnus* rise (from *ca* 7640±85 BP [OxA-4042] to 6515±85 BP [OxA-4041]; Day, 1995) and has been tentatively attributed to the actions of later Mesolithic peoples. Whilst there is considerable evidence of potentially anthropogenic burning in the charcoal records from Star Carr, none of the associated pollen records show any convincing indications of disturbance within the dryland vegetation. An outline diagram from lake-edge deposits at nearby Seamer Carr (East Island site E77 in Cloutman, 1988) does, however, show a period of decreased tree representation and increased levels of ruderal species coincident with the *Alnus* rise, which the author infers to be of later Mesolithic human origin.

2.4 Archaeological background

This section summarises the archaeological records of Holderness and surrounding areas in terms of the evidence that we have for patterns of settlement and other activity, from the Late-Glacial Period onwards. The sections are organised chronologically, starting with the Upper Palaeolithic and the locations of the sites referred to in the text are shown in Figure 2.7.

2.4.1 Holderness

For full listings of sites and artefacts, readers are referred to Loughlin and Miller (1979), Van de Noort and Davies (1993), and Van de Noort and Ellis (1995, 2000).

The Upper Palaeolithic

A uniserially barbed antler point was recovered from the deposits of an infilled kettlehole located close to the village of Gransmoor by Sheldrick *et al.* (1997). The point was embedded within a log, radiocarbon-dated to 11,475±50 BP (SRR-4920, Lowe *et al.*, 1995), which compares well with the estimated date given by the authors on stratigraphical grounds of *ca* 11.5-11 ka BP. This places the point within what is likely to have been one of the coldest parts of the Late Glacial Interstadial (LGIS; Sheldrick *et al.*, 1997). The authors suggest that it may have been part of a spear or arrow used for fishing. This is interesting given the presence of bones from perch (*Perca fluvialis*) within the deposit and the finding of a complete pike (*Esox lucius*) skeleton within what appear to be deposits dating from the early part of the LGIS in another kettlehole less than 2 km away. Whilst numerous other barbed points have been found in Holderness, they have generally been ascribed to the Mesolithic Period, and are subsequently discussed in the next section. Several worked flints dating typologically to the Upper

Palaeolithic Period have also been found across Holderness (Gilbertson, 1984a; Head *et al.*, 1995a, 1995b).

The finds suggest a human presence within Holderness for at least part of the Late-Glacial Period, although artefacts directly datable to the Younger Dryas are lacking. The antler point indicates that the wetland resources of the area may well have been utilised.

The Mesolithic Period

Writing in 1988, Schadla-Hall cites Holderness (particularly the north of the region) as one of the three most important areas in eastern and northeastern Yorkshire in terms of Early Mesolithic archaeology, the others being the Vale of Pickering and the North York Moors. He goes on to suggest that this is at least partly a reflection of the distribution of field archaeologists, with information from other areas possibly reflecting a lack of archaeological activity rather than a lack of archaeology *per se*. To an extent the inclusion of Holderness in this list highlights just how little Early Mesolithic archaeology is known from the rest of the region under discussion, with the Early Mesolithic archaeology of Holderness being comparatively much poorer than that of the other two areas. There is also a dearth of radiocarbon dates and palaeobotanical work relating directly to the artefacts from Holderness, with almost all finds being without context, and thus dated by typology alone (but see Godwin and Godwin, 1933 and Gilbertson, 1984a). This is in direct comparison with the situation in the Vale of Pickering and on the North York Moors.

Since Schadla-Hall made these comments, an extensive programme of fieldwalking as part of the Humber Wetlands Project has located further finds datable to both the Early and Late Mesolithic throughout Holderness (Head *et al.*, 1995a, 1995b; Chapman *et al.*, 2000). A large proportion of the artefacts datable to the Early Mesolithic have been found along the gravel ridge systems that run across northern Holderness, including a total of 13 barbed points from Brandesburton (Clark and Godwin, 1956; Bartlett, 1969; Radley, 1969; Davis-King, 1980). A further two points have been found near Hornsea (Clark and Godwin, 1956) and one from the deposits of Skipsea Withow Mere (Armstrong, 1923, but see Gilbertson, 1984a). Most of the above authors suggest

'Maglemosian' affinities for the points, but it may be that a distinction can be made between those manufactured from bone (12 out of the 16) and from antler (4 out of the 16). Wymer *et al.* (1975) suggest that the points made from bone generally represent an earlier technological phase than those recovered from Star Carr, and are thus datable to the earliest Holocene (the 'Pre-Boreal' Period) or the Younger Dryas. In addition, Van de Noort and Davies (1993) suggest that the points made from antler may be of a similar age to the finds from Star Carr (i.e. dating from the 'Boreal' Period). The lack of dating controls mean that caution must be exercised though and it seems likely that the finds reflect wetland exploitation over several millennia (Van de Noort *et al.*, 1995).

A large flint concentration was found on a hillside overlooking the Hull Valley at Brigham, around 6 km from Brandesburton, by Manby (1966) and although initially classed as 'Creswellian', the assemblage probably dates from the Early Mesolithic (Radley, 1969). Other Early (and later) Mesolithic flint assemblages have also been found in association with the esker system around Gransmoor (unpublished data). Late last century, excavations by Boynton (in Smith, 1911) identified a 'lake dwelling' at the site of Round Hill, near Skipsea which was assigned to the Late Neolithic or Early Bronze Age. A recent reassessment by Head *et al.* (1995a) and Van de Noort *et al.* (1995), however, suggests that the structure may represent a platform for hunting and fishing purposes. A radiocarbon date from an 'unsharpened alder stake' of 9080±100 BP (GU-5451) indicates that the structure may also date from the Early Mesolithic, which is particularly interesting given that its location close to a large mere is comparable with the site of Star Carr. If the date is indeed correct and from *Alnus glutinosa*, then the species may have been present in the area for a considerable length of time before it became palynologically visible. The concentrations of flints from the site date to the Late Mesolithic/Early Neolithic (Head *et al.*, 1995a), however, so the possibility remains that the structure dates from a similar period.

The bulk of the remaining Mesolithic assemblages either date to the later part of the period, or are not separable into early and later periods. Finds seem to be concentrated around the edges of the larger mere systems (notably Lambwath Mere and the complex of Skipsea Low, Bail and Withow Meres: Gilbertson, 1984a; Head *et al.*, 1995a; Van de Noort *et al.*, 1995), along the Keyingham Valley (Head *et al.*, 1995b) and on till outcrops and levees beside the River Hull (Chapman *et al.*, 2000; Van de Noort *et al.*, 2000). The finds data at present thus suggest a concentration of Mesolithic activity on both the elevated gravel ridges of northern Holderness (particularly within the early part of the period), around the larger lake basins and close to the River Hull. Further research may identify whether this reflects a real archaeological distribution, or is purely a function of site visibility.

Whilst the archaeological record suggests a human presence, there is little evidence for disturbance potentially attributable to Mesolithic peoples in the published pollen record (RPAZ's 1-3). The exception to this is the record from Sproatley Bog[1], where Flenley (1987) suggests possible Mesolithic disturbance on the basis of an outline pollen profile. Interestingly an axe-marked oak stump has been recovered from the site and radiocarbon-dated to 6310±80 BP (HAR-6626), indicating a human presence at the site during the later Mesolithic (Flenley, 1987).

The Neolithic Period

There are a greater number of artefact scatters and excavated sites dating to the Neolithic Period in Holderness than to the preceding Mesolithic Period, with the sites more evenly spaced across the region (although northern Holderness and the Keyingham Valley still stand out as areas with higher than average find densities).

A Neolithic occupation layer was found sealed beneath a Bronze Age round barrow at Easington in southern Holderness (Mackey, 1998). The occupation layer has yielded a great deal of information concerning the Neolithic in Holderness, representing the only proven occupation site in the area to be excavated and securely dated. A charcoal-rich horizon from the layer has been radiocarbon-dated to 2404±165 BC (BM-268), placing the occupation in the later Neolithic Period. Among the more interesting finds are a number of Peterborough Ware vessels, three clay hearths, fragments of saddle querns, and a ceramic loomweight. Numerous flints and several ground and polished stone tools were also recovered. It is clear that prior to the building of the barrow, the site was

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[1] Note that although the site is given as Sproatley Mere in Flenley (1987), it corresponds to the site of Sproatley Bog in this and other texts (Flenley, pers comm.).

occupied for a considerable length of time as an industrial and habitation zone, with there being evidence of a probable post built structure (Mackey, 1998). The only other potentially Neolithic structure known from Holderness is a later Neolithic or Early Bronze Age trackway at the site of West Furze, near Skipsea (Van de Noort, 1995). The site was initially excavated by Boynton (Smith, 1911), and again classed as a 'lake dwelling', but now appears to represent a trackway crossing Skipsea Low Mere at its narrowest point. A later platform lies above this and dates to the late Bronze Age at the earliest and although its function is unclear it may have been another crossing point, or perhaps part of a habitation site (Van de Noort, 1995). Whilst it was suggested by Gilbertson (1984b) that there was evidence at Skipsea Withow Mere for Early Neolithic management of alder carr and woodworking, the site has since been identified as that of a beaver dam and it seems likely that the worked wood represents the activity of the same animals (McAvoy, 1995). The fact that no Neolithic barrows have been securely identified in Holderness contrasts markedly with the situation on the Yorkshire Wolds where there is evidence for at least 34 ritual or mortuary sites (Manby, 1988).

Other finds from Holderness include a number of stone axes and numerous flint scatters (Head *et al.*, 1995a, 1995b; Chapman *et al.*, 2000). Six Grimston style pottery vessels have also been found in two pits near to Brandesburton (Head *et al.*, 1995a). Radiocarbon dates of 5000±70 BP (OxA-4411) and 4885±70 BP (OxA-4413) obtained from hazelnut shells from within the pits place the finds in the Early Neolithic, which together with the other evidence suggests a human presence in Holderness throughout the Neolithic period. Some continuity of exploitation is suggested, with the bulk of the artefactual evidence associated with the larger mere systems and estuarine inlets, as it was in the preceding Mesolithic Period (Head, 1995). The Neolithic period forms part of RPAZ 4, with evidence of disturbance that has been attributed to humans present in all of the pollen records covering this period by definition.

The Bronze Age

The area around Barmston and Skipsea has produced a number of Bronze Age structures. Excavations at Barmston uncovered a further 'lake dwelling' (Smith, 1911), more recently reinterpreted as a settlement in a marshy hollow surrounded by a seasonally flooded lake or fen (Varley, 1968). Radiocarbon dates of 2960±150 BP (BM-122) and 2890±150 BP (BM-123) obtained from timbers place the site within the Middle Bronze Age (Varley, 1968), with finds from the same locality indicating a continued human presence in both the later Bronze Age and Iron Age (Head *et al.*, 1995a). Aerial photographs suggest that a series of round barrows may once have been present at the site of West Furze, whilst a round barrow and possible Bronze Age burial have also been found at Barmston and Skipsea respectively (Head *et al.*, 1995a). Aerial photography has revealed further round barrows along the periphery of the Yorkshire Wolds, in northern Holderness (Loughlin and Miller, 1979). These finds along with the platforms at West Furze underline the importance of northern Holderness during the Bronze Age.

Further south, round barrows have been identified at Halsham and Roos (Loughlin and Miller, 1979), with a Beaker grave having been recovered from another at Easington Warren (Mackey, 1998). The Easington barrow is the sole survivor of a group excavated in the 1890s by a Dr Hewetson (see Mackey, 1998), the rest having since been lost through coastal erosion. Whilst there are a number of round barrow beaker burials, funerary evidence from the Middle and later Bronze Age is scarcer (Van de Noort and Davies, 1993). A later Bronze Age cremation cemetery has been found at Catfoss, near Seaton (Loughlin and Miller, 1979), and there is evidence of another dating to the late Bronze Age or Early Iron Age at Kilnsea (Van de Noort and Davies, 1993).

Three sewn-plank boats have been excavated from the Humber foreshore at North Ferriby, (McGrail, 1990). Further excavation has led Buckland *et al.* (1990) to suggest that the site may have been used for boat building and repair work, and that it was situated on a mudflat beyond an area of saltmarsh. Woodland management during the Early Bronze Age has also been suggested by the finding of an apparently *in-situ* coppiced alder stool at the Manor Farm site, Seaton (Head *et al.*, 1995a).

When the above data are supplemented by the comparatively large number of artefact finds (primarily flints and Bronze work) from the region (Manby, 1980; Dent, 1990; Head *et al.*, 1995a, 1995b; Chapman, 2000) and a number of possible Bronze Age cropmarks (Van de Noort and Davies, 1993), human activity throughout the period and across most of Holderness is suggested. Whilst a correspondence of activity with the wetland sites exploited in the Neolithic Period is still seen, Van de Noort *et al.* (1995) suggest that there is also evidence of a diversification of the wetland resources used to include smaller meres and stream systems. This observation may be significant, but it is possible that site visibility may again be a factor. The Bronze Age is likely to cover part of RPAZ's 4 and 5, and although the period only seems to be covered at The Bog at Roos, increases in both the extent and duration of human disturbances are observed.

The Iron Age

During the Iron Age, eastern Yorkshire formed a culturally distinct zone characterised by a burial rite found nowhere else in Britain. This has been termed the Arras culture, and comparisons with the burial styles of the La Tène peoples of mainland Europe have been drawn, inferring a link with the continent during the period (May, 1992; Cunliffe, 1995). Cunliffe goes on to suggest that the landscape was organised and comprised of village-like settlements and ditched fields linked by roadways. In the later Iron Age, the inhabitants of the area emerged as the Parisi (May, 1992), which was perhaps a continuation of the Arras culture (Cunliffe, 1995). It appears that the Humber Estuary acted as a frontier during the period, as shown by the distribution of the Early Arras culture, and the cultural differences between the Parisi to the north of the Humber and the Corieltauvi to the south during the later Iron Age (May, 1992).

Several settlement sites have been excavated within Holderness. Those at Thornham Hill and Hill Farm close to Gransmoor have indicated a mixed agricultural economy (Copley, 1953), with pottery from the Thornham Hill settlement having been dated on typological grounds to 400-200 BC (Manby: in Copley, 1953). At least nine enclosed settlements are known from Holderness (Van de Noort and Ellis, 1993), with a settlement at Burton Agnes comprising of a number of round houses within a stockaded enclosure and dating to the 5th century BC, having been likened to a hillfort (Challis and Harding, 1975). Other settlement sites include one dating to the late Iron Age or Roman period at Halsham and another dating to 395-79 BC (2155±50 BP, OxA-5487) near to Brandesburton (Head *et al.*, 1995a, 1995b). Square barrows have also been found along

Earls Dyke at Barmston and near Leconfield (Loughlin and Miller, 1979), and a possible chariot burial has been uncovered at Hornsea (Sitch, 1992). The bulk of the settlement and burial evidence from Holderness, however, comes from aerial photography. An extensive system of cropmarks exists across the region and many are suggestive of Iron Age linear ditches, enclosures and circular features (possibly hut circles [Van de Noort and Ellis, 1993]), although a degree of caution should be exercised in that the features are generally unexcavated and undated.

There are very few isolated artefact scatters from Holderness, particularly when compared to the Bronze Age, but fragments of pottery are scattered across the region (Head *et al.*, 1995a, 1995b), and in excess of 100 Late Iron Age coins have been found within the territory of the Parisi (May, 1992). The bulk of these coins are Coritanian or Corieltauvian and were found along the present-day coastline, suggesting trade activity with areas south of the Humber Estuary (May, 1992). Other important finds from the area include a carved wooden boat and four standing figures, the 'Roos Carr Images' (Poulson, 1840; Sheppard, 1902), which have recently been dated to 610-510 cal BC (2460±70 BP: OxA-1718, Coles, 1990). The items, which are approximately 40 cm high and made from pine, were recovered from a drainage ditch near to the village of Roos, and it seems likely that there may have once been a second boat (Coles, 1990). The full range of evidence implies considerable activity across Holderness within the Iron Age. It is likely that the Iron Age is represented within RPAZ 5, but given the lack of dating controls little more can be said.

The Roman Period

Although the Romans took control of the region south of the Humber in AD 43, it was not until AD 71 that they crossed into North Humberside via Winteringham (Eagles, 1979). A fort was erected within the territory of the Parisi at present day Brough (then *Petuaria*) in AD 71-72, primarily for defence against the neighbouring Brigantes (Wacher, 1974). Whilst many of the Parisi settlements were probably relatively undisturbed by Roman occupation (Allison, 1976), areas of denser settlement arose close to *Petuaria* and around present day Hull and Beverley (Eagles, 1979; Dent, 1990). It has been suggested by Eagles (1979) that the Hull Valley may have been the most prosperous region of Holderness during the Roman Period, and it is clear that alluvial deposits were settled as well as the higher gravel ridges (Didsbury, 1990). Whilst there are no known Roman villas in Holderness, Romano-British sites are scattered across the region, with examples being Skerne (Dent, 1983), Keyingham, Withernsea, Patrington (Van de Noort and Davies, 1993) and Kilnsea (Head *et al.,* 1995b). It is likely that the Roman and all later periods are covered by RPAZ 5, with sustained clearance activity indicated within the catchment of The Bog at Roos.

The Early Medieval onwards - a brief summary

The period between the end of Roman rule until that of widespread Anglian settlement remains poorly known (Van de Noort and Davies, 1993). The earliest evidence for Germanic peoples comes from late Roman cemeteries associated with military or urban settlements, with Eagles (1979) suggesting that troops were stationed in towns under Roman command from the end of the 3rd century AD. An increase in numbers is indicated in the decades leading up to the end of Roman rule, and it is possible that the first Anglian settlers were troops and their families (*ibid*). It is unclear when independent settlers arrived, but burial evidence suggests that Anglo-Saxon settlements were widespread across Holderness by the 7th century AD (Eagles, 1979; Loughlin and Miller, 1979; Van de Noort and Davies, 1993). The settlements are predominately located close to or on areas of gravel such as Nafferton and Hornsea (Eagles, 1979). From the 6th century onwards, the area around Driffield emerged as a centre of importance, with Driffield becoming a royal vill of King Aldfrith sometime before AD 705 (Eagles, 1979; Hirst, 1985). Christian buildings from the Early Medieval Period include a monastery at Beverley and Minsters at Kilnsea and Watton (Van de Noort and Davies, 1993), and it is possible that Aldbrough church also has Early Medieval origins (Hey, 1986). Little is known of the changes in the landscape of Holderness following the end of the Roman occupation, but it has been suggested that Romano-British settlements remote from towns and major roads may have survived relatively unchanged (Eagles, 1979). It is clear that by the later Anglo-Saxon period land ownership was based upon a manorial system of holdings (Faull and Stinson, 1986). Politically Holderness formed part of the Kingdom of Deira until AD 616 when it became encompassed within Northumbria (Eagles, 1979).

Towards the end of the 7th century and throughout the 8th century Holderness was raided by Scandinavian invaders (Binns, 1963). Danelaw was finally enforced following the invasion of northern Britain and the sacking of York by the 'great army' in AD 867 (Binns, 1963). With the exception of two periods of English rule, Northumbria remained under Danelaw until the defeat of Harold Hardrada in 1066 (Faull and Stinson, 1986). Artefacts dating from this period include stone crosses at Aldbrough, Barmston and North Frodingham (Binns, 1963), and a sword and spearhead from Skerne (Van de Noort and Davies, 1993). Other settlement evidence comes from place name endings (e.g. *-thorp* and *-by*; Binns, 1963; Fellows-Jensen, 1995).

Under Norman rule land was entirely reallocated, with the land of Holderness being divided between Archbishop Thomas, St. John's of Beverley and Drogo de Bevrere (Faull and Stinson, 1986). By far the greater part of Holderness was given to Drogo de Bevrere, one of William's soldiers, with Drogo in turn splitting the land between his men via an adaptation of the pre-existing manorial system (Faull and Stinson, 1986). Land ownership was passed onto Odo of Champagne in 1087, and from then it descended to the Earls of Albemarle (Faull and Stinson, 1986). It is clear from the Domesday Book that large tracts of Holderness were under arable agriculture both before and after the Norman conquest, with extensive areas of pasture and meadow, but little woodland (*ibid*; Rackham, 1994b). During the early period of Norman rule the motte and bailey castles of Skipsea Brough, Wawne and possibly Barmston were erected (Van de Noort and Ellis, 1993). A number of monasteries, friaries and convents from a range of religious orders were established in Holderness during the 12th-14th centuries, notably around Hull and Beverley (Burton, 1989; Cross, 1993). It was religious orders, such as the Cistercian monks at Meaux Abbey, that made the first serious attempts at land drainage in the 12th and 13th centuries (Sheppard, 1957; Hey, 1986). Much of the Medieval (and later) economy of the region relied upon the ports of Hedon (established between *ca* 12th-13th centuries) and Hull, which was made a head port by King John *ca* 1275 (Childs, 1990).

The pre-enclosure landscape of Holderness was one of villages surrounded by large, open fields and expanses of rough pasture and common ground (moor/waste; Harris, 1959). In the 18th century, the majority of the villages operated two-field rotational systems, and while it is unclear when the open field system originated, it seems likely that this type of landscape existed for a considerable period prior to this date (Hooke, 1998). The enclosure acts of the late 18th century created a different landscape of large rectangular fields, hedges and isolated farms (Wilkinson, 1956).

2.4.2 Comparison with the prehistory of surrounding areas

The Upper Palaeolithic

There is presently no securely dated Upper Palaeolithic material from the uplands of the North York Moors (Spratt, 1993b) or from the Yorkshire Wolds. There is, however, evidence of a human presence in the Vale of Pickering during the Late-Glacial, with concentrations of worked flint having been found at Seamer Carr (site K; Schadla-Hall, 1987, 1989) and Flixton Carr (Moore, 1954). Peat deposits from the level of a stone-lined hearth from Seamer Carr have been dated as 11,000±130 BP (HAR-5242; Schadla-Hall, 1989).

The Mesolithic

There is an abundance of material dating from the earlier Mesolithic in north-east Yorkshire, with a combined total of at least 30-40 sites on the areas of the North York Moors and the Vale of Pickering (Spratt, 1993b). The bulk of the finds on the Moors consist of flint assemblages, with sites being concentrated on the sandstone moorlands on and to the south of the central watershed, although there have also been isolated finds on the Tabular Hills (Spratt, 1993b). It has been suggested by Spratt that the Moors were not permanently settled during this period, but instead formed part of a seasonal exploitation zone. In the Vale of Pickering a number of sites have been located along the shore of the former lake Flixton, indicating a concentration of Early Mesolithic activity in the area. Some of the more important sites are those of Star Carr (see below), Flixton Carr (Moore, 1950, 1954) and Seamer Carr (particularly sites C and K; Schadla-Hall, 1987, 1988; see Figure 2.8). The site of Star Carr is probably the most famous Early Mesolithic site in Britain, and is certainly one of the most complete. The site has been a focus of attention since the original excavations by Clark in the early 1950s (see Clark, 1954) and has been the subject of ongoing research and reinterpretation (e.g. Jacobi, 1978; Legge and Rowley-Conwy, 1988; Mellars and Dark, 1998a). Star Carr lies on the shore of the former Lake Flixton and consists of an extensive occupation horizon, which includes a wooden platform or trackway (Mellars and Dark, 1998b). Mellars and Dark (1998b) suggest that the site was probably occupied in total for at least 300 yrs (i.e. from *ca* 10,700-10,400 cal BP). The site has yielded large amounts of worked flint and antler as well as numerous animal bones, with the latest interpretation being that it was probably occupied repeatedly from March or April until June or July (Mellars, 1998a). It is still debatable as to whether the site reflects a specialised camp, or a more generalised base camp (Mellars, 1998a), but it is clear that it was used for both hunting and the manufacture of tools. The combined evidence suggests extensive human activity in the Vale of Pickering both close to and distant from the former Lake Flixton during the earlier Mesolithic.

Finds dating to the later Mesolithic are abundant all over the North York Moors (*ca* 120 sites; Spratt, 1993b), but relatively infrequent in the Vale of Pickering. There is, however, enough evidence to suggest that both areas were occupied during the later Mesolithic, with Spratt (1993b) suggesting that the higher Moors may have become permanently occupied during the period.

Mesolithic material from the Yorkshire Wolds is very scarce, but flints have been found at Bridlington and in the Great Wold Valley (ref).

The Neolithic

There is evidence of Neolithic activity throughout the North York Moors on all but the highest ground (Spratt, 1993c). In the earlier Neolithic the greatest find density is on the Tabular Hills, with the density of long barrows, cairns and other finds being only slightly less than that on the Yorkshire Wolds (see below). It has been argued by Spratt (1993c) that this probably reflects the high fertility of the limestone based soils of the area. Finds and structures dating to the Late Neolithic/earliest Bronze Age from the Moors are less frequent, but a number of stone circles, cupstones, ringstones and flints have been found on the lower hills around the edge of the Moors (Spratt, 1993c). Whilst there are comparatively few Neolithic finds (Early and Late) from the Vale of Pickering, activity in the area around Seamer Carr is suggested as it was in the preceding Mesolithic Period (Spratt, 1993c).

There is a huge amount of archaeological evidence for the occupation of the Yorkshire Wolds during the Neolithic Period. There are at least eighteen long barrows dating from the Early Neolithic (Manby, 1988) some of which are of great size (e.g. Kilham II), with the excavation of a number of pits containing Grimston Ware pottery suggesting settlement sites across much of the area (Manby, 1975). Faunal evidence suggests that red deer (*Cervus elaphus*) and wild oxen (*Bos primigenius*) were hunted, and a breed of small short-horn cattle (cf. *Bos longifrons*) and pig (*Sus scrofa*) were kept as domestic animals (Pacitto, 1972; Manby, 1988). There is also a considerable amount of monumental archaeology from the later Neolithic, with a number of henge monuments (e.g. Haywold and Duggleby) and round barrows across the region (Manby, 1988). Several of the barrows are extremely large and have been termed 'Great Barrows', examples from the Great Wold Valley including Willie Howe and Duggleby Howe (see Riley, 1988). The Rudston Monolith (at 8 m height, the tallest prehistoric standing stone in Britain) stands at the centre of three cursus monuments on a spur of the Great Wold Valley (Manby, 1988), indicating that the area was of considerable ritual importance during the later Neolithic. Evidence for occupation sites is fragmentary, but indicates settlement across the Wolds (Manby, 1988).

The Bronze Age

Large numbers of Late Neolithic/Early Bronze Age round barrows, many containing Beaker burials, are scattered across the North York Moors, but concentrated on the lower areas (particularly the Tabular Hills [Spratt, 1993d]). A number of barrows and cairnfields are also present on the higher Moors, with the field evidence suggesting mixed farming (Spratt, 1993d). It has been proposed by Spratt (1981) that these represent seasonal farms, with the permanent settlements being located on the lower fringes. Later Bronze Age material is also concentrated on the lower areas and finds include several hillforts and an increasing amount of bronze work (Spratt, 1993d). A number of linear earthworks probably also had their origins in the later part of the period (Spratt, 1993d). The combined evidence suggests a continuation of the settlement pattern from the Neolithic (Spratt, 1993d). Evidence for Bronze Age occupation of the

Vale of Pickering is comparatively scarce, although a number of stone axe hammers, battle axes and items of bronze work have been found (see Spratt, 1993d).

In keeping with the preceding Neolithic Period, monumental evidence (primarily in the form of barrows), is plentiful on the Yorkshire Wolds. Around 90 % of these are round barrows dating from the earlier part of the period (Manby, 1980), with the main concentration of burials being on the high western Wolds (Pierpoint, 1981). However, settlement evidence is sparse in this area and is concentrated on the eastern side of the Wolds, where burial evidence, conversely, is infrequent (Pierpoint, 1981). During the later Bronze Age monumental burials are much rarer, with the few located burials being bucket or barrel urn cremation inhumations (e.g. Garton Slack [Manby, 1980]). Field and land boundaries start to become evident from *ca* 1400 BC, coincident with the first appearance of major defended settlements (Pierpoint, 1981). A series of linear earthworks are present in the Great Wold Valley, a dyke is present at Ladys Graves and hillforts include Grimthorpe and Thwing (Manby, 1980). Manby (1980) suggests a tendency towards the use of lowland sites in the later Bronze Age, with upland settlement being more characteristic of the earlier period.

The Iron Age

While there is relatively little dated archaeology from the early part of the Iron Age it is clear that population densities increased in both the Vale of Pickering and the lower areas of the Moors throughout the 1st millennium BC (Spratt, 1993e). It is likely that many of the linear earthworks and hillforts on the Moors were constructed or adapted during the earlier Iron Age (*ibid*). A similar pattern of settlement to that of the Bronze Age is seen during the later Iron Age, with barrows concentrated on the Tabular Hills and little evidence of settlement on the highest Moors (*ibid*). Although there is evidence for the continuation of settlement patterns and areas, individual settlements do not appear to have persisted. Finds dating from the Iron Age are scattered across the Vale of Pickering, and include several cart burials (*ibid*).

Iron Age evidence from the Yorkshire Wolds consists chiefly of funerary material (Stead, 1991). Single interment burial mounds surrounded by square or rectangular ditches have been excavated from sites such as Wetwang Slack (Dent, 1985), Rudston, Garton-on-the-Wolds, Kirkburn and Burton Fleming (Stead, 1991). Such barrows tended to be isolated during the 5th-3rd centuries BC, but aggregated into large cemeteries during the 2nd century BC (Van de Noort and Davies, 1993). Elite burials involving the interment of a chariot, or other two-wheeled vehicle (a characteristic of the Arras culture) have also been found at Wetwang Slack (Dent, 1984, 1985) and Kirkburn (Stead, 1991). The large number of square barrows scattered across the Wolds indicate a dispersed settlement pattern (Stead, 1979) and it is likely that small agricultural settlements were common (May, 1992), although larger settlements such as Staple Howe (Stead, 1991) also existed. It is clear that the larger Wolds valleys and the area around Danes Dyke on Flamborough Head were important activity areas (Stead, 1991). Across eastern Yorkshire there is evidence that settlements became more enclosed, and field systems were extended towards the end of the 1st century BC (Dent, 1983; Van de Noort and Davies, 1993).

2.5 The Holocene development of the North Sea Basin

It has long been recognised that an area of land linked eastern England with the European mainland throughout the Late-Glacial and for part of the Holocene (Reid, 1913; Clark, 1936). The development and loss of this land mass has been studied by a number of authors (e.g. Jelgersma, 1961, 1979; Eisma *et al.*, 1981), with a comprehensive review having been recently provided by Coles (1998). This exposed land mass (termed 'Doggerland' by Coles) would have provided an important migration route and an occupation zone (*ibid*). Its presence and loss is important in the context of this study, and is likely to have influenced both the environment and habitation of Late-Glacial and Early Holocene Holderness through resource availability, cultural exchange routes and climate. A brief overview of the development, landscape and archaeology of the North Sea Basin will be given below so that the development of Holderness already outlined (sections 2.3.1.1 and 2.3.2.1) can be viewed in context with the changing land area of the region through the Holocene.

Reconstruction of the development of the landbridge is far from easy, although hypothetical maps have been constructed by Jelgersma (1979) and Coles (1998). The maps of Jelgersma (Figures 2.9 and 2.10) are the most widely used, but differ from the more recent reconstructions of Coles (Figure 2.11) in several key areas, notably the areal extent and timing of loss of the land mass most closely linked to modern day Holderness. The maps are primarily based upon relative sea-level curves, the dating of freshwater peats dredged from the North Sea Basin and present day submarine topography (see Coles for full discussion). Whilst it is tempting to take these maps as good approximations of the Holocene dynamics of the North Sea Basin, they should be interpreted cautiously with Coles stating that:

"At present, there is insufficient evidence to do more than note that marine conditions were established in the southern North Sea between c. 7000-5000 BP" (Coles, *ibid*, p. 67).

This places a very approximate timescale for the loss of the linkage, although some land may have remained exposed after the bridge was lost. Pollen and macrofossil analysis from recovered peat deposits has given an idea of the vegetational environment, with macrofossils of *Betula, Salix* and *Corylus* having been identified by Reid (1913) from Dogger Bank. Whilst pollen and stratigraphical analyses are biased towards wetland areas (Verhart, 1988), it is likely that drier habitats also existed, particularly around the 'Dogger Hills' (Coles, *ibid*, see Figure 2.11). It seems probable that the Holocene vegetational development was intermediate between that of mainland Europe and England, with open *Betula-Juniperus-Salix* scrub in the earliest Holocene, and *Corylus, Quercus* and *Ulmus* (and possibly *Alnus* and *Tilia*) creating a mixed woodland as they migrated-in.

A considerable number of artefacts dating to the Early Mesolithic have been recovered from the North Sea, with the main find sites shown in Figure 2.9. The finds consist almost totally of worked antler and bone, with the lack of flint perhaps due to the loss of small items through dredging (although Verhart [1995] notes that larger items such as cores and axes should still be recovered). Barbed antler and bone points have been recovered from the Leman and Ower Banks (Burkitt, 1932), the Hook of Holland

(Verhart, 1995), Monster (Verhart, 1988) and washed up at Whitburn (Mellars, 1970). In excess of 500 points dating from the period between *ca* 9950-8060 BP have also been recovered from Europoort (Verhart, 1988, 1995). Other artefacts include a number of bone axes, adzes and picks from Scheveningen (Verhart, 1995), and worked bone and antler fragments from Brown Bank (Louwe Koojimans, 1972). The finds have generally been assigned to the earlier Mesolithic, which agrees with the Europoort dates, and are mostly indicative of wetland exploitation. The similarity of the find locations (amongst a wetland landscape) and artefact types to those recovered from Early Mesolithic Holderness is striking, but perhaps not surprising given that Holderness was once part of the same land mass and on the basis of the available evidence of very similar landscape character.

Chapter 3: Research strategy: site selection, core location and sampling interval

3.1 Introduction

The purpose of this chapter is to explain the site selection criteria, coring, and sampling strategies employed in the study and to describe the chosen study sites. The principal requirements and selected criteria/strategies are given in section 3.2 as a series of topics, with the relevant theory reviewed at each stage. The spatial and temporal implications of the chosen strategy are then discussed in section 3.3. Finally, the field sites are introduced and described in section 3.4. The exact field methodology and laboratory techniques employed in the study are discussed in chapter 4.

3.2 Site selection, core location and sampling interval

The principal aim of this thesis was to produce four Holocene vegetational histories from localities within central Holderness, thus producing a high spatial resolution picture of the vegetational development of a geographically constrained area. In order to be able to detect short-term events, high temporal resolution sampling was employed. The high concentration of peat and lacustrine deposits in Holderness meant that a strict regime of site choice could be followed to optimise these aims, with the following sections discussing the main criteria for site selection and the chosen sampling strategy.

3.2.1 Site location, type and size

All four sites had to be located in central Holderness and as one of the intentions was to look at variation in landscape development, it was felt important that the pollen catchments of the sites did not overlap significantly. Whilst there are peat deposits in central Holderness (e.g. in the Roos Valley), many are desiccated, disturbed and temporally restricted and were judged unsuitable for study. Instead it was decided to analyse the sediments from within a series of infilled lake basins, as the sites provided better temporal coverages and contained well preserved material. It was considered preferable for the basins to be situated on comparatively elevated ground so that site development was largely independent of the changing hydrology of the valleys and the deposits contained records reflecting the vegetational development of the drier and more freely draining areas of land, on which settlement is more likely to have occurred. The location of the sites at broadly similar elevations (between 10-20 m OD) and in similar landscapes (gently undulating) meant that differential pollen recruitment due to variations in aspect and altitude should not be significant (cf. Markgraf, 1980). In order to maximise the temporal resolution that was obtainable the basins had to contain as great a depth of deposit as possible (the chosen sites all contained in excess of 3.5 m of Holocene deposits).

The palynological effects of a watercourse such as a natural stream entering a basin have been noted by a number of authors. In the high rainfall area of the Lake District, Bonny (1978) observed that streamborne pollen can contribute up to 85 % of the pollen entering a lake basin, whilst in other upland areas this value can be in excess of 90 % (Peck, 1973). The landscape around the site and watercourse is also of importance, with work by Pennington (1979) showing that the streamborne component to a site in northern England increased from less than 50 % to greater than 80 % when the wooded landscape was cleared. Given the potential importance of this component two points are of relevance to this study. It has been shown that such an input can qualitatively alter the pollen assemblage and hence distort the pollen record obtained. Bonny (1976, 1978) notes the increased representation of pollen types that are poorly dispersed by air in lakes with inflowing streams, whilst Hirons (1988) argues that pollen distant from the study site (including non-contemporaneous inwashed pollen) introduced via a stream was sufficient to mask a sequence of vegetational disturbances attributed to human action around the site of Lough Nanallog, County Tyrone. Secondly, stream interaction is going to affect the pollen catchment by extending it to include the watershed of the stream itself, hence distorting the pollen catchment in the direction of the stream. Given that one of the key aims of this study was to produce a series of spatially constrained vegetational histories, it was felt important to chose sites that were isolated from incoming watercourses as far as could be ascertained.

The recruitment of pollen to a site is dependent upon a range of factors including pollen production and dispersal attributes, the character of the landscape, and the depositional environment (Delcourt and Delcourt, 1991). Whilst the combination of processes acting mean that any discussions of pollen catchment are necessarily vague, the potential exists for the palynologist to gain the desired level of spatial resolution through careful site choice (Jacobson and Bradshaw, 1981). Indeed it is imperative that the pollen assemblages obtainable must be related to vegetation composition at the spatial scale of interest. This is particularly relevant in ecological studies as patterns and processes are scale-dependent, and the visibility of such processes is dependent to a large extent upon the pollen source area of a site (Sugita, 1994). For example a disturbance of small areal extent is likely to be masked in a basin that collects pollen from a source area of much greater extent than the disturbance. The main sources of pollen to a lake basin are shown in Figure 3.1. The pollen source area of a lake basin is primarily controlled by basin size (Jacobson and Bradshaw, 1981). Janssen (1966) proposes that the pollen in a basin can originate at a series of distances from the site and whilst essentially arbitrary these groupings serve as useful working definitions, particularly when modified according to Jacobson and Bradshaw (1981; see Table 3.1). Pollen from all of these groups enters a lake basin, but it is the relative contribution of each type that defines the spatial resolution of the record obtainable (Jacobson and Bradshaw, 1981). As a general rule, large lake basins collect pollen from a wider area than basins with smaller areas of open water and hence are suited to reconstructing regional vegetation patterns (Jacobson and Bradshaw, 1981; Bradshaw and Webb, 1985). It follows that small sites dominated by the local component are best suited to investigating local vegetation patterns and small scale disturbances.

As this study was concerned with the reconstruction of the vegetational landscapes around four sites, it was felt preferable to select basins having pollen recruitment dominated by the extra-local component (i.e. pollen originating from within several hundred metres of the site). Jacobson and Bradshaw (1981) suggest that in a wooded landscape this component dominates the pollen record in lake basins of *ca* 1-5 ha in size (which compares favourably with the simulated pollen dispersal model of Prentice [1985]). As local input becomes increasingly important towards the lower end of this range and regional input towards the upper end (Figure 3.2), their data indicate that a basin of *ca* 2-4 ha would be preferable. Sugita (1994) observed that pollen loading (the pollen input to the surface of the basin, PL) is linearly related to the distance-weighted plant abundance (DWPA) around the basin. As individual plants distant from the basin have less influence on PL than individuals that are closer, the correlation between PL and DWPA should reach an asymptote as distance from the basin increases. The relevant source area (RSA) is then defined as the distance beyond which the correlation does not improve, pollen from beyond this distance effectively forming the background record and the RSA thus becoming the smallest area of landscape that can be reconstructed from a pollen assemblage (Sugita, *et al.*, 1999). Sugita (1994) went on to adapt the model of Prentice to incorporate the entire basin surface and to include patchy vegetation, and suggested that 30-45 % of the pollen loading for a 50 m radius lake (0.78 ha) originates from within 300-400 m of the basin edge, this figure increasing to 600-800 m for a basin of radius 250 m (19.63 ha). These figures equate to the RSA and support the above conclusion that a basin of *ca* 2-4 ha will be dominated by pollen originating within several hundred metres of the basin (i.e. <300-500 m).

Whilst the results of these models are less certain when equations allowing for unstable wind conditions and pollen dispersal from the canopy (in contrast to ground level) are incorporated (Jackson and Lyford, 1999), the general conclusion remains that basins of 2-4 hectares in size are most appropriate for gaining the level of spatial resolution required in this study. It should be noted though that there is no direct equation between basin size and catchment area and that the pollen catchment will vary through time as the basin size changes and hydroseral succession progresses. The source area is also dependent upon the landscape, with the regional component increasing in contribution as the landscape becomes more open (Pennington, 1979; Fossitt, 1994; Sugita *et al.*, 1999). Finally, the catchment will also vary according to pollen type due to the differential production and dispersal abilities of plant taxa (e.g. Tauber 1965; Andersen, 1973; Bradshaw, 1981; Prentice, 1988).

In order to minimise differences in recruitment due to variation in the pattern of site development, the basins chosen had to be broadly similar in character, with the chosen sites all being steep sided and of probable kettlehole origin. A summary of the chosen site criteria is given in Table 3.2.

3.2.2 Coring strategy and core location

Single sediment cores were obtained from each site. Whilst multiple core approaches have shown the potential problems of relying on the vegetational record from a single core (e.g. Whittington *et al.*, 1991; Sugden, 2000), given the time constraints of the study and the relatively untested nature of the approach in small, deep lowland basins, such a strategy was not employed. The cores were obtained from the deepest undisturbed areas of the basins in order to maximise the temporal resolutions of the records. A number of studies have shown convincingly that focusing of sediment from shallower to deeper areas often occurs (e.g. Davis *et al.*, 1973; Lehman, 1975; but see Dearing, 1983; see Figure 3.1), and whilst the magnitude and spatial pattern of sediment focusing can vary within a lake through time (Jackson, 1994) it is likely that the greatest temporal resolution will be obtained from the deepest deposits. A second concern was that the cores should be located away from the lake-edge. This was decided for several reasons. Firstly, lake-edge deposits are susceptible to periodic drying and may subsequently contain poorly preserved pollen and provide less-continuous records than more centrally located sequences. Secondly, intense reworking, disturbance and erosion often occurs along lake margins (Davis, 1968, 1973; Bonny, 1978). Finally, lake-edge pollen records can be biased towards nearby or overhanging vegetation (Bonny, 1978).

3.2.3 Sampling interval

The sampling interval was chosen to provide the maximum temporal resolution within the time available. All cores were sampled at the initial resolution of every 4 cm, with areas of interest sampled at the finer interval of every 2 cm. In addition, 1 cm contiguous sampling was employed in key areas to maximise the level of ecological information gained.

3.3 Interpretational implications of the selected research strategy

The chosen sites and sampling strategy have important interpretational implications, particularly concerning the scales of disturbance that will theoretically be visible in the records obtained. Delcourt *et al.* (1983) and Delcourt and Delcourt (1988) discuss the idea that all ecological systems are essentially hierarchical in nature, with patterns and processes at one spatio-temporal scale incorporating all of the processes and relationships included in lower levels, and being bounded by conditions at higher levels. They define a series of scales as shown in Figure 3.3, with the processes and vegetation types that these categories contain being shown in Figure 3.4. The visibility of a given process thus depends upon the relationship between the spatio-temporal resolution of the research strategy and that of the process itself (Delcourt and Delcourt, 1988). Although the temporal resolution of this study means that many of the micro-scale patterns are potentially visible, the sites were chosen on theoretical grounds to provide landscape-scale spatial records. Whilst it is impossible to define precisely the area that this represents, on the basis of section 3.2.1 it is probable that the area of vegetation dominating the pollen record corresponds to the vegetation unit of the sub-type (Figure 3.4). This suggests that changes within individual woodland stands will not be visible as discrete events, a conclusion that is supported by pollen records from forest hollows which suggest that in wooded environments these considerably smaller basin types can only just resolve stand-scale composition (e.g. Mitchell, 1988; Calcote, 1995). The records obtained in this study will thus be averages of the vegetational mosaic in space and, because the sediment samples for analysis were 1 cm thick, also over time (perhaps *ca* 5-20 yrs depending on sediment accumulation rate). Data concerning species abundance and vegetation composition will hence be integrated (*sensu* Jackson, 1994) over an area that includes the vegetation growing within at least several hundred metres of the basin. This means that many natural ecological processes, such as patch dynamics and species heterogeneity due to soil type and microtopography, will not be evident in the pollen spectra beyond the level of maintenance of diversity. This does not implicitly mean that the data cannot be interpreted in terms of ecological process.

Significantly, the fact that most naturally formed canopy openings in boreal or broad-leaved woodland tend to be of tree or stand size in scale (Bazzazz, 1983; Pickett and White, 1985; Peterken, 1996) means that they will not show directly in the record. This implies that any disturbance event that is visible as a discrete canopy opening or successional deflection is likely to have been of abnormally large (catastrophic *sensu* White, 1979) aggregate spatial extent, whether natural or anthropogenic in origin. This greatly simplifies interpretation as any changes visible will be of landscape significance. The exact scale of any canopy opening that will be visible is undefinable, although Sugita *et al.* (1997) suggest that an opening around a 3 ha lake basin located within boreal woodland in Canada must be of the order of 8-10 times larger than the basin itself to be detected. Whilst the applicability of this data to the present study is uncertain, of interest is the observation that the disturbance must occur within the RSA otherwise it is masked by the background pollen rain, in the above case this means from within a few hundred metres of the shoreline. Whilst the RSA varies by taxa, site and vegetational landscape this is an encouraging finding.

The above discussion does not help discern the effects of many small openings from one large opening, or a large scale relatively distant disturbance from that of a smaller, closer one (cf. Edwards, 1979, 1982). However, a consideration of the total areal extent of vegetation change that is necessary before a disturbance (or suite of disturbances) becomes visible greatly aids the interpretation of the data and allows for more powerful conclusions. In this study it is clear that the spatial resolutions of the chosen study sites mean that any disturbances that are visible must be significant landscape-scale events. Whilst the discussion has centred upon a wooded to patchy environment, as the landscape becomes more open Sugita *et al.* (1999) predict that the RSA will be increased significantly and hence the interpretational parameters will change. Although the ideas discussed above are perhaps oversimplified, they form a basis for interpretation.

3.4 Site descriptions

The chosen study sites of Cess Dell (*ca* 4 ha), Gilderson Marr (*ca* 3 ha), Sproatley Bog (*ca* 2.5 ha) and The Bog at Roos (*ca* 2 ha) are discussed in detail below to aid the interpretation of the environmental records obtained. A key to Figures 3.5-3.8 is provided in Figure 3.9.

3.4.1 Cess Dell

Cess Dell (NGR TA 259378) lies on a flat plain at the base of a gently sloping hillside at an altitude of between 10-15 m OD, and is 1.5 km southeast of Aldbrough and 1 km inland of the present coastline (Figure 3.5 and Plate 3.1). The basin probably originated as a kettlehole and is *ca* 4 ha in size, containing in excess of 7.2 m of freshwater deposits at the deepest located point. The core location is shown on Plate 3.1. Although Dinnin and Lillie (1995a) reported deposits in excess of 9 m that included pollen suggestive of a cleared agricultural landscape, these were not located during fieldwork. If found then the potential of a record from the site spanning a greater time range exists.

The infilled basin is capped by up to 1 m of colluvium and although the watertable was approximately 1 m below the ground surface at the time of coring, the underlying peat remained waterlogged. The bulk of the site is presently under pasture although the margins (particularly those to the southeast and northwest) are beneath arable land and regularly ploughed. Cess Dell is bisected by the Cess Dale Drain, but despite these drainage attempts the site still floods occasionally in winter. The site supports a rough grassland with frequent patches of *Juncus effusus* and scattered individuals of *Ranunculus bulbosus* and *Trifolium repens.*

Cess Dell lies in an area with very little known prehistoric archaeology, the only finds of significance being occasional artefact scatters, two possible round barrow sites and a number of cropmarks that may possibly date from the prehistoric period (Figure 3.5).

3.4.2 Gilderson Marr

Gilderson Marr (also called Gills Mere, NGR TA 299331) lies in a shallow valley approximately 1.25 km north of Tunstall and 400 m from the present coastline (Figure 3.6 and Plate 3.2). The basin fills much of the valley and is approximately 3 ha in size, and contains in excess of 6 m of deposit covering the Late-Glacial and part of the Holocene (see chapter 7). The basin is dissected by two drains, with a fishpond also having been recently dug (Plate 3.2). The spoil from the digging of the pond and the drains is scattered on the surface to the southeast of the pond. Although the site is beneath arable land a layer of colluvium (in excess of 50 cm thick) protects the deposits, and despite the drains the basin frequently floods in winter. A core was taken from the central deposits where disturbance appeared minimal (Plate 3.2).

The area around Gilderson Marr is by far the poorest of the study sites with respect to known archaeology, with no pre-Iron Age material recorded, although it is possible that an undated cropmark to the west of Tunstall may have prehistoric origins (Figure 3.6).

3.4.3 Sproatley Bog

Sproatley Bog (TA 205344) lies at an altitude of 10-15 m OD in an area of flat land 1 km east of Sproatley and 9 km inland from the present coastline (Figure 3.7 and Plate 3.3). It is a steep-sided basin of approximately 2.5 ha, and contains at least 5.9 m of deposit covering the Late-Glacial and part of the Holocene. The site lies amongst extensive arable farmland and is much disturbed. It is bisected by a drain, with the deposits to the north of the drain having been partially removed to form a fishpond. The upper deposits to the south of the drain have also been disturbed and are partially covered by waste from the drain cutting, with spoil having created a small artificial island. To the immediate north of the island the deposits are relatively undisturbed and it was from here that the core was obtained (Plate 3.3). This is a fairly central position, but may not represent the deepest area of the basin. The margins of the site lie beneath frequently ploughed arable land.

The vegetation around the site is essentially ruderal, with herbs such as *Urtica dioica, Epilobium hirsutum, Chamaenerion angustifolium, Galium aparine* and Apiaceae dominant. *Filipendula ulmaria* is common alongside the drain with the area to the south of the drain supporting a dense bed of *Typha latifolia* and *Sparganium.*

Cores from the site have been sampled for pollen at low temporal resolutions by Robinson (1986) and Mather (1988) as undergraduate dissertations, and it is on the basis of the first study that Flenley (1987) reported evidence of Mesolithic disturbance. An axe-marked oak stump dated to 6350 BP±80 BP (HAR-6626) has also been recovered from the site (Flenley, 1987). During fieldwork a scatter of worked flint was found along the southeastern edge of the basin, but it was not possible to assign the debitage to a fixed period. Besides the data already discussed there is scant evidence for prehistoric activity in the area around the site, although the presence of at least three deserted Medieval villages suggests considerable activity in historical times (Figure 3.14).

3.4.4 The Bog at Roos

The Bog at Roos (NGR TA 273288) is a SSSI located 1.75 km southwest of the village of Roos and 5.25 km inland of the present day coastline (see Figure 3.8 and Plate 3.4). The basin is approximately oval with a surface area of *ca* 2 ha and occupies a hollow in the Late Devensian Withernsea Till. The Bog has no natural inflows or outflows and probably originated as a kettlehole or pingo (Beckett, 1975). It is almost completely surrounded by a rim of higher ground (5-13 m OD) which isolates it from the low-lying Roos Valley. This has resulted in the site being largely unaffected by the alluviation and peat formation that occurred in the Roos Valley during the Mid to Late Holocene (see section 2.3.2.1).

A previous palynological study by Beckett (1975, 1981) suggests that the deposits span the Late-Glacial and most of the Holocene. Although its SSSI status and dense on-site vegetation precluded the taking of a transect from the site, Beckett (1975) was able to obtain transect data and showed that the deepest deposits were located within the centre of the basin. A core was subsequently obtained for analysis from the approximate centre of the site (Plate 3.4).

Beckett (1975) reports that the surface of the bog was comparatively dry prior to 1968, being drained by a series of ditches leading to an outflow pipe at the north end of the site and eventually into the Keyingham Drain. The bog surface supported a damp woodland flora beneath a canopy of *Betula, Quercus robur* and a patch of *Larix*, so it is possible that the uppermost deposits may have experienced considerable mixing. In 1968 the basin was flooded to provide water for crop irrigation, killing the trees. By 1975 the site was covered by up to 1 m of standing water, with patches of *Salix* and *Phragmites communis* beginning to colonise the shallower areas. The site now supports a dense *Salix* carr, with some *Betula* and an understorey dominated by *Urtica dioica.* Stands of *Iris pseudacorus, Phragmites australis* and *Typha latifolia* are common in the damper areas, in particular towards the centre of the basin. At the time of coring the water table was approximately 50 cm beneath the peat surface. The drier slopes around the basin support a ruderal herbaceous community, with occasional individuals of *Crateagus monogyna, Fraxinus excelsior, Ulmus,* and *Sambucus nigra.* The area around the site is currently under arable agriculture.

A number of flint scatters dating to the Mesolithic, Neolithic and Bronze Age have been found close to the site (see Figure 3.8), which together with the Iron Age 'Roos Images' found from the Owstwick Drain (see 2.4.1) mean that the archaeological record is considerably greater than that from around the other study sites. The extent to which this may be a reflection of visibility and time spent fieldwalking is uncertain.

Chapter 4: Methodology

4.1 Introduction

This chapter discusses the field and laboratory methods employed in the study. The techniques used are outlined and relevant theoretical considerations discussed. Section 4.2 overviews the main field techniques. The palynological methods employed are discussed in section 4.3, with other laboratory techniques described in section 4.4. Data presentation is summarised in section 4.5.

4.2 Field methods

4.2.1 Coring technique

A single core was obtained from each site (see section 3.4 for detail) using a Russian pattern corer (Jowsey, 1966) with a chamber length of 50 cm and an internal diameter of 8 cm. The type of deposit and the approximate positions of any stratigraphical transitions within the profile were noted in the field along with the Munsell colour (Munsell, 1992). This was done immediately to minimise any error caused by oxidative colour change of the deposit due to prolonged exposure to air. The cores were then placed on a section of drainpipe, wrapped in polythene, labelled and stored at 4 ° C.

4.2.2 Vegetation survey

A survey of the present day vegetation on and immediately surrounding the site was undertaken, with nomenclature following Stace (1997). Throughout the text, the terms tree, shrub and herb are as defined in Stace (1997), whilst heaths incorporates dwarf heathland shrubs (in this study Ericaceae and *Empetrum nigrum* only).

4.3 Pollen analysis

4.3.1 Sample preparation

4.3.1.1 Pollen grain measurement and processing considerations

The present study uses several approaches to distinguish important pollen types by their morphological characteristics (primarily pollen grain size). In particular the techniques employed to distinguish between the pollen of *Cannabis sativa* and *Humulus lupulus*, those within the family Poaceae (see chapter 5), and the genus *Betula*, rely on observations concerning morphological variation within and between species. Care was taken to ensure that the choice of material for measurement and the chemical preparation technique minimised the risks of biasing the results by altering pollen grain sizes.

The principal factors that were considered in this context are summarised below (for further discussion see Mäkelä, 1996):

Grain maturity
Pollen size varies with grain maturity (Gronlund, 1995: in Mäkelä, 1996) and should only be a major concern in modern pollen studies where pollen may be removed from plant specimens before it is fully formed (Mäkelä, 1996). In the present study this could conceivably be a problem if catkins, for example, were to fall from overhanging vegetation into the site. To minimise the risk of this, grains that were aggregated into groups of a single pollen type were not measured for use in statistical analysis (such clumping was only observed for *Alnus* and *Betula* grains and then only rarely).

Altitude and latitude (climate)

An increase in grain size with altitude and latitude has been demonstrated for European *Betula* species (Usinger, 1980), although these geographical variations have been seen as insignificant by other workers (Faegri and Iversen, 1989). As the sites studied do not vary greatly in either attribute, then even if these observations are significant and widely applicable, any data presented here should be internally consistent for any one climatic period. The changes in climate observed during the Holocene, however, may equate at the level of the pollen grain to an altitudinal or a latitudinal change and this was borne in mind when interpreting the data.

Sedimentary environment

Sedimentary environment can also affect grain size (Christensen, 1946; Andersen, 1978; Mäkelä, 1996), but is hard to quantify in the laboratory. In the present study the possibility was considered, particularly where a size change coincided with a change in stratigraphy, although no further quantification was attempted.

Laboratory technique

Finally, laboratory technique can have a considerable affect on pollen grain size. It has been observed that acetolysis causes an increase in grain size compared to treatment with $KOH_{(aq)}$, and $HF_{(aq)}$ may cause grains to shrink (Faegri and Iversen, 1989). Whether this latter effect is due to the chemical treatment itself (Faegri and Iversen, 1989), or due to the sediment chemistry of such highly siliceous samples (Moore *et al.* 1991) is unclear. Grain size can also be affected by mounting medium and slide thickness. In the present study, samples were mounted in silicone oil in order to avoid the problems of grain-swelling over time as observed with the use of other mounting media such as glycerol (Andersen, 1960; Moore *et al.*, 1991). Given the observation of Andersen (1979) that grain size may still change slightly with prolonged storage in silicone oil, all samples were counted and any measurements taken within 2 weeks of sample preparation. Where further measurements were necessary at a later date, fresh samples were prepared. The use of silicone oil also allowed grains to be rotated, aiding identification and measurement. Care was taken not to over-compress the coverslip, as a distance between coverslip and slide of less than the largest grain diameter can cause shape distortion and hence imprecise measurements (Cushing, 1961).

4.3.1.2 Processing method

The processing methodology was chosen to provide maximum comparability with the work of other analysts and to ensure internal consistency, particularly with respect to the concerns outlined above.

Each core was sub-sampled for pollen at the temporal resolutions described in section 3.2.3. With the exception of Sproatley Bog, only the regions of the cores corresponding to the Holocene Period were sampled (i.e. those stratigraphically above the inferred Late-Glacial clays). 1 cm^3 of wet sediment was taken from along the central axis of the core using the volume displacement method of Bonny (1972). To allow determination of absolute pollen concentrations, spores of *Lycopodium clavatum* were added in tablet form as exotic marker grains (Benninghoff, 1962; Stockmarr, 1971). Low frequencies of *Lycopodium* undiff. spores (<1 % TLP+Spores), which could have been from the species *clavatum*, were found at two levels in Beckett's (1975, 1981) analysis of a core from The Bog at Roos. This was not felt to present a significant enough problem to warrant the use of an alternative marker species.

Samples were prepared using the standard preparation techniques of Faegri and Iversen (1989) and Moore and Webb (1991). The method was standardised, with the only variable being whether the sample was treated with $HF_{(aq)}$. This was noted and borne in mind when considering pollen size measurements. To minimise the risk of damaging grains and darkening organic material by prolonged oxidation, an acetolysis duration of 2 minutes was used (cf. 3 minutes in Faegri and Iversen, 1989). Full details of the preparation technique are given in Appendix 2.

4.3.2 Pollen counting and identification

For most samples a minimum of 500 total land pollen grains (TLP) were counted, with the exception of the Late-Glacial deposits of Sproatley Bog (496-404 cm), where the extremely low pollen concentrations necessitated a reduced count of 250 TLP. This should still be a sufficient count size to show any changes in the principal pollen types (Faegri and Iversen, 1989). To allow for the presence of high levels of *Cannabis*-type pollen above 154 cm in the Sproatley Bog core, and the swamping of the record by *Alnus* pollen at Cess Dell above 284 cm, the additional constraint of a minimum of 300 TLP excluding the respective pollen types was also employed.

Identification of pollen grains was carried out using a Zeiss microscope at a magnification of x400, with x1000 oil immersion and phase contrast used for critical determinations and for all measurements. All measurements were taken where possible in polar view and to the nearest 1 μm.

Grains were identified using the keys of Punt and den Breejen (1981), Punt (1984), Punt and Malotaux (1984) and Moore *et al.* (1991), and by reference to a comprehensive type collection. Nomenclature follows Bennett (1994), with any exceptions shown in Appendix 3. The methodologies for the separation of tree from dwarf birch and *Cannabis sativa* from *Humulus lupulus* pollen are outlined below, whilst the identification of Poaceae pollen is discussed in detail in Chapter 5.

Betula

It has been suggested by a number of authors that it may be possible to distinguish between species within the genus *Betula* using morphological criteria (e.g. Birks, 1968; Gordon and Prentice, 1977; Prentice, 1981; Mäkelä, 1996). Birks (1968) reports that it is possible to separate *B. nana* (dwarf birch) from *B. pubescens* (downy birch) on the basis of the ratio of grain diameter to pore depth, whilst *B. nana* can be distinguished from *B. tortuosa* (mountain birch, *B. pubescens ssp. tortuosa*) by its smaller grain size. In a more recent study Mäkelä (1996) showed that pollen from *B. nana* could be separated from that of tree birches (including silver birch, *B. pendula*) on the basis of size frequency distributions. In her study, based upon analysis of pollen from modern Scandinavian populations, the mode of the frequency distribution for *B. nana* lies around 16 µm, whilst those of the tree birches lie between *ca* 19 and 23 µm.

In the present study a similar approach to that of Mäkelä was used to investigate whether there was any discernible *B. nana* component in the site records during the early Holocene. Given the relatively similar ecological tolerances of *B. pendula* and *B. pubescens,* the fact that hybridisation frequently occurs between the species (Grime *et al.*, 1988), and the observation of Mäkelä (1996) that pollen grains of the two species are inseparable in modern material, no attempt was made to distinguish between the tree birches.

The longest axes of *Betula* grains (from outer exine edge to the end of a pore) were measured from levels before, during and after the initial *Corylus avellana*-type rise, with all measurements taken at x1000 magnification and to the nearest 1 µm. Only well-preserved grains were measured and all measurements were taken in polar view, with the sample size being 50 for each level. The data is presented as a series of smoothed size-frequency graphs in the relevant results chapters. The smoothing formula used is $(n_1+2n_2+n_3)/4$, where n_1, n_2 and n_3 are the number of grains in three adjacent size groups (cf. Kolstrup, 1982; Edwards and Whittington, 1997).

Cannabis-type

The *Cannabis*-type pollen group of Moore *et al.* (1991) consists of *Cannabis sativa* and *Humulus lupulus*, two ecologically and culturally very different species. Whilst *Humulus* pollen is generally smaller than that of *Cannabis,* there is considerable overlap between the size-frequency distributions (Punt and Malotaux, 1984; Whittington and Gordon, 1987). The degree to which the pores protrude provides a more secure method of separation, with *Cannabis* pores more likely to protrude in excess of 1 µm than those of *Humulus* (French and Moore, 1968). Work by Whittington and Gordon (1987) suggests that although populations of both species contain individuals with both protruding and non-protruding pores, the measurement of pore protrusion characteristics from a large enough sample allows the estimation of the contributions that the two pollen types make to the population.

In the present study *Cannabis*-type pollen was encountered at The Bog at Roos and Sproatley Bog. Although the numbers of grains encountered at The Bog at Roos were too small to make statistical analysis a viable approach, both grain diameter and pore protrusion were noted for all grains located (see chapter 9). The higher levels of *Cannabis*-type pollen at Sproatley Bog meant that statistical analysis could be employed. The grain diameter (including pore) in polar view and pore protrusion were measured for grains from the depths of 96, 92 and 88 cm (n=100), and 136, 120 and 108 cm (n=20). Size-frequency distributions are presented along with estimates of the proportion of the sample that is likely to be *Cannabis*, calculated using the equation and data of Whittington and Gordon (1987) given below:

Proportion of *Humulus* pollen in sample = $(P_C-f)/(P_C-P_H)$

Where P_C= proportion of *Cannabis* grains with raised pores (0.9496)

P_H= proportion of *Humulus* grains with raised pores (0.0416)

r= number of grains in sample with raised pores (>1 µm)

n= sample size

f= r/n

4.3.3 Pollen preservation

The relationship between the pollen assemblage recovered by the analyst and the vegetation communities that it represents is a notoriously difficult one to quantify. This is partly due to inter-species variation in pollen production and dispersal attributes, differential deposition and reworking of pollen within the basin, and bioturbation (see chapter 3). Pollen grains are also preserved differentially, further altering the assemblage. However, far from confounding the analysts interpretative problems, a knowledge of the preservation state of the grains can greatly improve the understanding of the depositional and wider environments over time. Questions concerning the modes of transport of the grains, along with how reliable the record is, can be approached.

4.3.3.1 Deterioration types

Although there is a growing body of experimental and observational data concerning the different types of deterioration and their causes, there is still much to be learnt, reflecting the complexity of the processes involved. A summary of each deterioration type used in this study is given below:

Corroded

This refers to grains with exines that are pitted, perforated or locally etched (Cushing, 1967) and has been termed 'cavitation' by Havinga (1984). Some authors also use the term to include gradual exine thinning (Havinga, 1964; Holloway, 1989). Corrosion can be caused by chemical oxidative agents (Havinga, 1964; Brooks and Elisk, 1974), by repeated wet and dry cycles (Holloway, 1989), and by bacterial (Havinga, 1964) or fungal (Goldstein, 1960) action. Experiments suggest that chemical or biochemical oxidation may be necessary before any microbial attack can occur (Havinga, 1964, 1967, 1984) and that grains differ in their susceptibility to corrosion (Sangster and Dale, 1961, 1964). This is likely to be due to species-specific variation in the form and amount of sporopollenin contained (Sangster and Dale, 1961). Although the idea that grains are naturally oxidised in aerobic environments has not been entirely proven (Havinga, 1964), corrosion susceptibility parallels oxidation susceptibility in the laboratory. In biologically-inactive soils the dominant form of corrosion is thinning, whilst cavitation dominates in biologically-active environments (Havinga, 1984). This implies that cavitation is at least in part caused by the actions of micro-organisms, which does not necessarily contradict the observations of Rowley *et al.* (1990) that the exine features of cavitated grains are structurally comparable with the results of chemical experiments.

Degraded/amorphous

Such grains are waxy in appearance with diffuse structural and sculptural elements that can only be resolved with difficulty (Cushing, 1967; Lowe, 1982). Significant proportions of amorphous grains have been observed in silts and sands (Cushing, 1967;

Birks, 1970), soils of low biological activity (Havinga, 1984), and in association with reworked Pre-Quaternary microfossils (Birks, 1970). It is likely that the process may entail both physical and chemical alteration of components of the exine (Lowe, 1982).

Broken

Broken grains have a distinctly ruptured exine in one or more place and have been associated with silts and sands (Birks, 1970), representing mechanical damage to the grain. Although turbid water transport has been shown to be ineffective at causing breakage of grains (Campbell, 1991), it is likely to be important in some situations. Other probable causes include physical compaction or deformation and ingestion by invertebrates (Lowe, 1982). Breakage is likely to be greater in grains that have previously been thinned.

Crumpled

Crumpled grains are badly twisted or folded along more than one axis (Cushing, 1967). It is likely that crumpling forms in similar conditions to breakage, representing mechanical damage to the grain, with the condition having been associated with silt, and algal copropel (Birks, 1970).

Indeterminable

Indeterminable grains are too damaged to be identifiable, concealed or simply unknown to the analyst. Indeterminable damaged grains can be classed in a similar way to the determinable damaged grains above.

Such processes can act prior to, during and after deposition, with a summary diagram of the stages at which a grain may be damaged presented in Figure 4.1. The processes of pollen deterioration are clearly complex and care must be taken when interpreting the data.

4.3.3.2 Methodology

All land pollen grains (excluding Cyperaceae) that were located during standard pollen counting were categorised according to their state of preservation. Cyperaceae were excluded from the damaged pollen sum as they exhibited a tendency to be almost entirely broken or crumpled in all of the samples looked at, perhaps due to their thin exine. As such any information gained by their inclusion would be minimal. The hierarchical system proposed by Cushing (1967), and adapted by Lowe (1982), was used if a grain exhibited more than one type of damage. This placed the damage types in the following order: corroded, degraded, crumpled, broken, well preserved. Hence, a grain that was both corroded and degraded would be classed solely as corroded, and one that was both crumpled and broken as crumpled only. It is appreciated that this is a purely artificial hierarchy and it is not meant to imply that e.g. corrosion is a more extreme or important form of damage than crumpling. Rather, the system was used as it is a quicker than that of Delcourt and Delcourt (1980) and allows maximum comparability with the work of other palynologists. An important flaw is that prominence will be given to the types higher in the order (Lowe, 1982), hence the proportions of grains that are crumpled and broken will be under-represented, placing limits on any interpretation.

The classes crumpled and broken are as defined previously, with the term amorphous being used in preference to degraded as in Lowe (1982). Corroded grains refer solely to cavitation, with thinning corrosion not being quantified as it is a particularly subjective category, especially when slight. It was noticed during counting that there was evidence for two distinct types of cavitation (see Plates 4.1-4.4). Comparable types are shown in Havinga (1964) and Havinga (1984), but as far as the present writer is aware the possibility has not been discussed that they potentially reflect different deterioration processes. If the case, then the splitting of cavitation corrosion into two classes may increase the level of information that can be gained. Cavitated grains have thus been classed as Type-1 (the 'approximately circular perforations in one or more layers of the exine' of Havinga, 1984, pp. 541; see Plates 4.1 and 4.2), and Type 2 ('scars of a rosette or meandering type', *ibid*, pp. 541; Plates 4.3 and 4.4). The exception to this is the site of Sproatley Bog where the data has not been split into these categories.

Indeterminable grains were assigned using a similar system, with the additional classes of concealed and unknown.

4.3.3.3 Processing considerations

To take into account the observation of Tipping (1987a) that in certain circumstances the addition of exotic marker tablets may cause clumping of pollen and enhanced levels of crumpling, it was ensured that the tablets were fully dissolved in $HCl_{(aq)}$. This was done prior to the determination of the sample volume (see Appendix 2). A shortened acetolysis time of 2 minutes was also used to ensure that the process did not cause undue oxidative damage to the palynomorphs.

4.4. Additional laboratory techniques

4.4.1 Organic carbon content

Organic carbon content was calculated using the technique of loss-on-ignition. This method was chosen as it is quick and produces reliable results (Håkansson and Jansson, 1983) particularly for non-calcareous sediments such as those used in this study (Allen *et al.*, 1974). Wet sediment samples of approximately 2 cm^3 in size were dried at 105°C for 12 hours, left in a desiccator to cool and weighed on a balance accurate to 2 decimal places. The dry samples were then combusted at 550°C for 2 hours to remove any organic material, cooled again in a desiccator and reweighed. The percentage loss-on-ignition was then calculated (Bengtsson and Enell, 1986). This combustion temperature was chosen to ensure that weight errors caused by the loss of carbonate or structural water from any clays in the samples were kept to a minimum.

4.4.2 Iron pyrite spherules

Iron pyrite spherules (FeS_2) are formed in conditions of low redox potential where organic matter, metallic ions and standing water coincide (see Wiltshire *et al.*, 1994 for further detail). Their presence in palynological preparations has been used by the above authors to indicate waterlogging and minimal bioturbation of the deposit. It was this latter consideration which encouraged assessment of spherule content in this study.

In the current study the abundance of iron pyrite spherules in the pollen preparations was noted. In general all iron pyrite spherules of >10 μm in diameter that were located during standard pollen counting were quantified, but where spherule abundance was particularly high, spherules were counted until a minimum of 10 exotic grains had been scanned. Spherule abundance is presented as the ratio of spherules to exotic pollen grains, as in Wiltshire *et al.* (1994).

4.4.3 Microscopic charcoal

4.4.3.1 Theoretical background

The usefulness of quantifying microscopic charcoal levels in order to investigate the anthropogenic and natural fire history of a region has been discussed by many authors (e.g. Tolonen, 1986; Patterson *et al.*, 1987; Bennett *et al.*, 1990; Edwards, 1990, 1998; Tipping, 1996). A number of important questions remain though in particular concerning the taphonomy and interpretation of the record. The relationship between charcoal source area and basin size is poorly understood, hampering attempts at defining the spatial location of a fire. Patterson *et al.* (1987) suggest that the source area for charcoal may be similar to that for pollen, although other work suggests that local fires may be comparatively under-represented as the light particles lift high into the atmosphere and are deposited long distances from the source (Clark, 1988; MacDonald *et al.*, 1991). The authors thus suggest that large charcoal particles better reflect local fires, although Edwards and MacDonald (1991) give evidence for a correspondence between the levels of both large and small particles in profiles from Scotland. More work is clearly required before firmer conclusions can be made. It is presently not possible to identify the type of vegetation that has been burnt either (but see Umbanhowar and McGrath, 1998), further constraining any interpretation. The behaviour of charcoal particles once within a basin is becoming more completely understood, with Bradbury (1996) and Whitlock and Millspaugh (1996) discussing the dynamics in detail. Whitlock and Millspaugh (1996) suggest that charcoal accumulation in deep water sediments may lag several years behind the fire event due to basin processes and secondary input from waterborne charcoal. Their data also suggest, encouragingly, that the signal from a known fire forms a discrete peak, the width of which depends upon the extent of compaction of the deposit and the degree of secondary inwash. It follows that the shape of the peak may be more a reflection of the taphonomic processes acting than the amount of biomass burnt (*ibid*). Data from the same region (Yellowstone National Park) suggests that the above processes result in peak widths of 1-3 cm for known historical fires, which equate to up to 20 years of accumulated sediment (Millspaugh and Whitlock, 1995). One further interpretational constraint is that it is not possible to distinguish between natural and anthropogenic burning solely on the basis of the charcoal record, with any conclusions being based primarily on inference (Tipping 1996).

4.4.3.2 Methodology

Despite the observations of Tolonen (1986) there is still no standard method for the quantification of charcoal levels, with the procedure used depending upon the personal preference of the analyst, the deposit characteristics and the research questions being approached. Given the observation of Clark (1984) that fragmentation of charcoal particles can occur during preparation procedures and the time-consuming nature of assigning particles to size classes, such an approach was not used (cf. Waddington, 1986). The point count method of Clark (1982) was also felt to be unsuitable, as in sediments with low charcoal abundance a value approaching zero can often be obtained (Patterson *et al.*, 1987). It was decided to calculate the area of charcoal per unit volume using microscope eye-piece grid squares. As the technique is greatly influenced by sediment accumulation rate (Swain, 1973), charcoal to pollen ratios were also calculated. It was felt that these techniques offered the best chance of gaining accurate results quickly, whilst providing internal consistency. Care should be taken when comparing the data with results gained using different techniques, although general trends should show an element of comparability.

Only particles that were opaque, black and angular (Clark, 1982) were counted to avoid problems of misidentification with either iron pyrite or dark organic material. As such the values obtained are likely to be minimum estimates as partially charred particles will be ignored. The exact calculation methods are given in Appendix 4.

4.4.4 Scanning for large Poaceae pollen

The occurrence of cereal-type pollen grains in pre-Elm Decline deposits has been noted by several authors (Edwards and Hirons, 1984; Edwards and McIntosh, 1988). If these grains are indeed from cultivated grasses, then their identification is potentially of great significance in charting the initiation and spread of arable agriculture within the British Isles and beyond (Edwards, 1998). To improve the detection rate of any large grass pollen within the cores analysed, the technique of scanning was used (Edwards and McIntosh, 1988), enabling large numbers of grains (*ca* 10,000 TLP per level) to be searched accurately and rapidly. Where pollen concentrations were particularly low, reduced counts down to *ca* 5000 TLP were necessary and the statistical effects of such variations in count size should be borne in mind when interpreting the data. Any Poaceae grains located with a longest axis of greater than 37 μm were measured carefully at x1000 magnification (see chapter 5). The exact scanning technique is shown in Appendix 5.

Samples covering the initial *Alnus* rise and either side of the first *Ulmus* decline were scanned, with the section of the core prior to the earliest large grass grain in each period being sampled at 1 cm resolution. In addition scanning was used to investigate a period of possible cereal cultivation identified in the core from The Bog at Roos, and of probable Neolithic date.

4.4.5 Plant macrofossils and insect remains

The upper section of the Sproatley Bog core (151-47 cm) was sampled for plant macrofossils and insect remains in order to investigate the hypothesis that *Cannabis sativa* and/or *Linum usitatissimum* plants may have been soaked (retted) within the basin, as discussed in chapter 8. The core was divided into 5 cm sections (90 cm^3 of deposit) and wet sieved through brass sieves of mesh size 1 mm and 300 µm. The residues were sorted and identifications made using a low power binocular microscope. Plant macrofossils (primarily seeds) were identified using Beijerinck (1947), Godwin (1975), Berggren (1969, 1981), Anderberg (1994) and by comparison with a reference collection. Help was also given by Dr Mike Charles, Dr Allan Hall and Amy Bogaard. Nomenclature follows Stace (1997). Coleopteran remains were identified by Sarah Clark and references for the Coleopteran data were compiled using the 'Bugs' database (Buckland *et al.,* 2000).

4.4.6 Statistical techniques

Detrended Correspondence Analysis (DCA) was used to investigate the relationships between the pollen spectra obtained within each profile (chapters 6-9). As for Principal Components Analysis (section 5.3.3.1), the technique is a form of multi-dimensional scaling and can be used to produce 2- or 3-dimensional representations of multivariate data (Maddy and Brew, 1995). This can show associations between variables that may not be evident to the naked eye. DCA performs eigenanalysis on a similarity matrix calculated from the original data and produces new axes of variation that account for as much of the variance contained within the dataset as possible (*ibid*). In general, the bulk of the variation is accounted for by the first few axes. Each variable is also assigned a score and by plotting the variable scores against the chosen axes, associations between the data (e.g. samples and/or pollen types) can be explored. In this study, DCA was used to investigate the relationships between different pollen zones and the principal taxa (i.e. pollen types exceeding 2 % TLP in at least one sample). Plots of taxon scores and mean pollen zone scores for the first two axes of the ordinations are presented in the relevant results chapters (chapters 6-9). A more detailed description and evaluation of the technique is provided by Maddy and Brew (1995).

4.4.7 Radiocarbon dating

AMS radiocarbon dating was used to produce an independent chronology for the Holocene sections of each core. Funding for a total of 44 AMS analyses was provided by the Natural Environment Research Council (Radiocarbon Dating Allocation numbers 738/0498 and 756/0998). The samples were prepared to graphite in East Kilbride and sent to the University of Arizona NSF-AMS Facility for radiocarbon analysis. Sample locations were chosen with reference to the pollen diagrams produced, with the main aims being to date the expansions and declines of the major tree taxa, to assign timescales to any episodes of vegetation disturbance and to date any significant changes in the charcoal record. Further samples were also chosen at regular intervals to improve the accuracy of interpolation, particularly across any transitions in sediment type. The samples taken from the sites of Sproatley Bog and Cess Dell were 2 cm thick, whilst those from Gilderson Marr and The Bog at Roos were 1 cm thick.

In general, dates are quoted as uncorrected radiocarbon years BP, with errors at 1 SD unless otherwise stated. Calibrated dates (cal BP or cal AD/BC) were calculated using CALIB Revision 4.0 (Stuiver and Reimer, 1993) using Method B. This calculates the area under the probability curve, with the calculated age ranges corresponding to the 68.3 % (1 SD) confidence interval (i.e. there is a 68.3 % chance that the real calendar age falls within the calculated range). All calibrated dates are presented as the mid-point of this age range. Interpolated dates were calculated using a programme contained within Tilia 2.0.b.4 (Grimm, 1991). In all cases linear interpolation was used. Although no errors are quoted alongside these dates it should be noted that the errors associated with the estimates are likely to be at least as great as those given for the actual radiocarbon dates.

Details of the dates are given in the relevant results sections (Chapters 6-9), with a complete listing of all uncalibrated and calibrated dates in Appendix 6. All dates are rounded to the nearest 10 years following Stuiver and Reimer (1993).

4.5 Data presentation

4.5.1 Pollen data

All raw pollen data were inputted into Tilia 2.0.b.4 (Grimm, 1991) and percentages, concentrations and accumulation rates calculated. Percentages are based on the sum of total land pollen (TLP), where TLP includes trees, shrubs, heaths (dwarf heathland shrubs) and land herbs. Any exceptions to this are stated in the appropriate results sections. Tilia•graph 1.25 (Grimm, 1991) and Tilia•graph View were used to produce the relative, absolute and accumulation rate diagrams presented in chapters 6-9. Charcoal to pollen ratios are based on the concentration of TLP. Plant macrofossil and insect data were also inputted into Tilia 2.0.b.4, with diagrams showing the raw counts being presented in chapter 8. Pollen diagrams were zoned objectively with the aid of the FORTRAN-based program CONISS found within Tilia. The technique is a form of stratigraphically constrained cluster analysis, with comprehensive reviews being given in Grimm (1987) and Bennett (1996b).

The method of Fossitt (1994), was used to calculate arboreal (AP) to non-arboreal (NAP) pollen ratios, where AP includes trees and shrubs, and NAP heaths, land herbs and spores.

4.5.2 Deteriorated pollen data

Data was compiled using Tilia 2.0.b.4 (Grimm, 1991) and is presented as a series of graphs in the format of Lowe (1982), adapted to include the two categories of cavitation previously discussed. All graphs were produced using Tilia•graph 1.25 (Grimm, 1991) and Tilia•graph View. In addition, formal Local Damaged Pollen Assemblage Zones

(LDPAZ's) were assigned with the aid of CONISS (Grimm, 1987). Zonation was carried out using the total values for each deterioration category, rather than the data for individual pollen types. This was done in order to emphasise the overall trends and to minimise the potential effects of differential susceptibility between taxa.

Chapter 5: Investigations into the separation of Poaceae pollen

5.1 Introduction

The purpose of this chapter is to investigate and discuss the separation of wild Poaceae from Cerealia pollen, with reference to the detection of arable agriculture within the pollen records from the study sites. The theoretical background is discussed in section 5.2 together with the approaches used in this study. Results of the analyses are presented in section 5.3 and concluding comments are made in section 5.4.

5.2 Background and approaches used

5.2.1 Theoretical background

The separation of pollen within the family Poaceae is notoriously difficult, but with care a number of authors have suggested that it may be possible to distinguish cultivated genera (*Avena, Hordeum, Secale* and *Triticum*) from most wild grasses (e.g. Firbas, 1937; Beug, 1961; Andersen, 1979; Küster, 1988). Firbas (1937) noted that cereal pollen is generally larger than that of undomesticated species and that by plotting frequency distributions of grain size it may be possible to detect the relative contribution of cultivated taxa to the pollen record. A more comprehensive modern pollen survey has been carried out by Andersen (1979) who suggests that Poaceae pollen can be separated into four groups using annulus diameter as the primary characteristic and mean grain size and surface pattern as secondary characters (Table 5.7). His data show that *Secale cereale* can often be identified to species level due to its prolate shape (the species has a pollen index of >1.26; see Table 5.1 for explanation), although identification of other cultivated species is less certain. *Hordeum vulgare* and *Triticum monococcum* pollen (contained within his *Hordeum* group) cannot usually be separated using his approach from a number of wild taxa including the wetland genus *Glyceria* (see Table 5.7). Further refinement may be possible within this group if measurements are accurate and the sample size is sufficiently large to create annulus diameter and size-frequency distributions. Cultivated *Avena* and *Triticum* species are also felt to be inseparable and are placed in the *Avena-Triticum* group, although closer examination of his data suggests that it may be possible to separate *Triticum* grains with large annulus diameters from *Avena* (his Table 3; *ibid*). This group also contains the wild taxon *Avena fatua*, which is likely to have been a significant arable weed in post-Bronze Age cereal crops (Godwin, 1975; Dickson, 1988).

Other characteristics that may be used to help separate cereal from wild grass pollen include pore diameter and the type of annulus. Beug (1961) proposes that in combination with grain size, the thickness of the annulus in polar view can be of use, with the annulus protruding more in cereals than most wild grasses. He also states (along with Faegri and Iversen, 1975) that cereals tend to have a more distinct outer annulus boundary. Küster (1988) incorporates the conclusions of Beug (1961) in his key (Table 5.8) and suggests that pore diameter, the ratio of annulus diameter to pore diameter, and the thickness and appearance of the annulus can be used to separate Poaceae pollen of >40 µm grain size into five groups (four of which are applicable to most European studies). He suggests that cereal pollen has an annulus that protrudes significantly in polar view and has a sharp outer boundary, and a relatively large annulus diameter compared to pore size, but notes that several wild species are indistinguishable from cereals on the basis of these characters (see Table 5.8). Annulus form has also been used by Vorren (1986) to distinguish between the pollen of *Hordeum vulgare* and *Elymus repens*, the former taxon having a more protruding annulus and a steeper outer annulus margin than the latter.

Finally, surface sculpture can also be of use in distinguishing between some Poaceae species (Beug, 1961; Andersen, 1979), with Andersen suggesting that members of his *Hordeum* group have a scabrate surface pattern whilst those of his *Avena-Triticum* group are verrucate. He states, however, that a degree of morphological variation exists within species.

As a summary, a number of authors have attempted to distinguish between the pollen of wild and cultivated Poaceae with varying degrees of success. *Secale cereale* is perhaps the most reliably identifiable European species, having a prolate grain shape (Andersen, 1979) and an eccentrically positioned (i.e. off-centre) pore (Beug, 1961), although O'Connell *et al.* (1999) note the occurrence of grains inseparable from *Secale* in Late-Glacial deposits from Ireland. Pollen from *Hordeum, Avena* and *Triticum* cannot be securely identified to genus level and is incorporated into groups containing at least one undomesticated species. A knowledge of the ecology of the relevant wild species can help to limit the number of possible non-cultivated taxa from which the pollen within these groups may have originated.

The above conclusions make interpretation of the large Poaceae pollen record difficult, and comparison between sites or regions is further hampered by the variety of identification methods that are used by different researchers (Dickson, 1988). Despite these interpretational problems, the separation of large Poaceae pollen can still be of great help in charting the initiation of arable farming in a region and in detecting changes in land-use practice through time and space (e.g. Edwards, 1979: Edwards and MacDonald, 1991; Bartley and Chambers, 1992; Willis and Bennett, 1994; Edwards, 1998). An attempt at the accurate identification of Poaceae pollen was consequently felt to be of considerable importance in this study. The large number of Poaceae grains of >37 µm mean grain size (referred to as 'large Poaceae grains' in this thesis) located during laboratory analysis encouraged the detailed assessment of the usefulness of current techniques in identifying the sub-fossil pollen to types. Of particular interest was the ability of different techniques to reliably separate the pollen of wild from cultivated taxa.

5.2.2 Approaches employed in this study

Pollen was classified using the keys of both Andersen (1979) and Küster (1988) and the results compared. The key of Andersen was chosen as it is the method most frequently employed by palynologists to separate wild from cultivated grass pollen, and because it is primarily based upon measurements of annulus diameter, mean grain size and pollen index (Table 5.7). This compares with the method of Küster which sets a size boundary of >40 µm and then separates the family into groups on the basis of pore and annulus characteristics, including annulus protrusion and outer boundary form (Table 5.8).

The large set of grains from this study also allowed a series of questions to be approached using multivariate statistical techniques (principal component analysis and discriminant analysis; see section 5.3.2). As far as the present writer is aware, this approach has not been used in any currently published studies.

In order to provide the data necessary to assess the above approaches, a series of attributes were measured from Poaceae grains located during laboratory analysis having a longest axis of at least 37 µm and an annulus diameter of 8 µm or above (see Table 5.1 for detail). All measurements were carried out to the nearest 1 µm at x1000 magnification and care was taken not to over-compress the coverslip, as this has been noted by Cushing (1961) to cause distortion of the pollen grain. With the exception of the type of annulus boundary (attribute I in Table 5.1), all characteristics are objective measurements and their derivatives. Although surface pattern has been shown to be of use in the separation of Poaceae pollen (see above) it was not noted in this study. This was because surface pattern will only be clearly visible in well-preserved grains and the degree of variation in surface sculpturing within pollen types is uncertain (Andersen, 1979). Assessment of the characteristic is also subjective and subsequently likely to vary according to pollen analyst. Whilst the same argument applies to the assignment of annulus boundary type, the characteristic is integral to the key of Küster (1988) and was included in this study. Some caution should be applied when comparing the following results with the work of other analysts, therefore, although care was taken to ensure internal consistency.

The grain size of Poaceae pollen has been shown to vary according to preservation conditions and chemical treatment (e.g. Andersen, 1978; 1979; Faegri and Iversen, 1979; see also section 4.3.1.1). Andersen (1979) has demonstrated that grain size can be standardised (for some species at least) by comparison with the grain diameter of *Corylus* in order to counter such affects, but that standardisation of annulus diameters is unnecessary. Whilst of potential use, standardisation of grain size was not attempted in this study due to time constraints and in view of the particularly low levels of *Corylus* *avellana*-type pollen present in the upper parts of the profiles from Sproatley Bog and The Bog at Roos (chapters 8 and 9). Similarly, although Andersen also recommends the production of size-frequency diagrams in order to aid identifications, this was not attempted for all of the data. Mean grain size- and annulus size-frequency diagrams were produced for the Sproatley Bog data, but it was felt that little additional information resulted and the diagrams are not presented here.

Attempts were made to measure all of the attributes described in Table 5.1 for each large Poaceae grain, but this was not possible in a number of cases due to poor preservation or because the grains could not be observed in the required orientation. The numbers of large Poaceae grains with complete (n_{comp}) and incomplete (n_{incomp}) data for each profile are given in Table 5.2. Only grains for which the data are complete are included in the following analyses, with full n_{comp} data for each site being provided in Tables 5.3-5.6.

5.3 Data analysis

The interpolated ages of the large Poaceae pollen grains located during this study fall into four broad age groupings (Table 5.9) and it is these categories that form the basis of the following discussions. It is highly unlikely that any pollen within groups 1 and 2 (*ca* 10,100-9600 BP and *ca* 8050-6800 BP, respectively) originates from cultivated species, the groups considerably pre-dating the earliest known indications of arable farming within Britain (see Table 5.9). Although extremely long distance transport could theoretically result in occasional cereal pollen grains reaching Britain from e.g. the Near East (Edwards, 1989), the finding of numerous grains within each profile during these periods makes this unlikely. Groups 3 and 4 on the other-hand may include pollen from both wild and cultivated species. Given the presence of these groups in the profiles from all study sites (where appropriate) and the care taken when preparing samples, it seems unlikely that any of the groups result from contamination.

5.3.1 Pollen keys: results and discussion

The Andersen (1979) and Küster (1988) types assigned to each large Poaceae grain are presented by site in Tables 5.3-5.6. An asterisk alongside the Andersen type indicates a grain with a pollen index consistent with *Secale cereale* (i.e. above 1.26), but a central (rather than eccentric) pore position. Such grains were interpreted as distorted (i.e. compressed) *Hordeum*-type or *Avena-Triticum*-type grains and assigned to these groups on the basis of annulus diameter and mean grain size. This approach was employed to limit the number of distorted grains that might be erroneously identified as *Secale cereale*.

The ecological preferences of the wild grass species included within cereal containing categories of Andersen and Küster were also considered in order to limit the number of wild taxa from which the pollen may have originated, and hence simplify interpretation of the data (Table 5.10). The inland locations of Sproatley Bog and the Bog at Roos mean that it is unlikely that coastal species contributed significantly to the pollen records from these sites. Although Cess Dell and Gilderson Marr are located closer to the present day coastline, the North Sea is likely to have been distant from the basins during the periods covered by the site profiles (see sections 2.2.1 and 2.5 and Figures 2.9-2.11), and it is also unlikely that coastal species are represented in the records from these sites. The species *Ammophila arenaria, Elymus farctus* and *Leymus arenarius* are subsequently excluded from the following discussions.

The remaining wild taxa occur in shaded woods (*Elymus caninus*), wetlands (*Glyceria*) and on open, disturbed, or cultivated ground (*Avena fatua, Bromus inermis, Elymus repens, Hordeum murinum* and *H. secalinum*). Full details are given in Table 5.10.

5.3.1.1 Group 1 (*ca* 10,100-9600 BP)

Although dating is relatively insecure during the earliest Holocene sections of the profiles, the grains included within this group all occur prior to, or during, the initial

Corylus avellana-type rises within the site pollen catchments. Large Poaceae grains occur at all four study sites during this period and given their ages they must be presumed to originate from wild grasses. Ecological conditions clearly favoured the growth of a wild grass taxon (or wild taxa) capable of producing large pollen grains. Catchment vegetation during this period was broadly similar and dominated by open *Betula* and/or *Betula-Corylus avellana* woodland.

A total of 45 large grass grains are contained within this group, with 32 corresponding to Andersen's (1979) *Hordeum* group, 9 to his *Avena-Triticum* group and 4 grains not fitting any of his categories. Several points are of interest. Firstly, a number of wild species with ecologically feasible habitat preferences are included within the *Hordeum* group (Table 5.7), and it is quite possible that the grains could originate from the wetland genus *Glyceria* or the disturbed ground taxa *Bromus inermis, Hordeum murinum* or perhaps *Elymus repens*. The grains falling within his *Avena-Triticum* group are harder to explain, with *Avena fatua* the only wild taxon included within this category. Godwin (1975) suggests that the species may not have reached Britain until the Iron Age, when it occurred either as a weed amongst *Avena sativa* crops, or as part of a mixed-species crop, and Dickson (1988) indicates that the species was a frequent weed in post-Bronze Age crops. If the taxon was indeed absent from pre-Iron Age England then this implies that the pollen must originate from cultivated *Avena* or *Triticum* which is highly unlikely. A more feasible suggestion is that other wild taxa are capable of producing pollen with the characteristics of Andersen's *Avena-Triticum* group.

Finally, the four grains that do not fit his categories (GM-5, GM-8, GM-10 and RBO-15; Tables 5.4 and 5.6) all have mean grain sizes of 39-39.5 μm and annulus diameters of 11-12 μm. The annulus diameters place the grains within the *Avena-Triticum* group, but the mean grain sizes of slightly <40 μm, mean that they cannot be included within this category (see Table 5.7). It seems likely that these grains are a reflection of overlapping size ranges between species, a potential problem indicated by the data of Andersen's Table 3, but not explicitly discussed by the author.

The grains included within group 1 cover all of Küster's categories, with 27 identified as Small Poaceae-type, 3 as *Glyceria*-type, 3 as *Arrhenaterum*-type and 3 as *Bromus hordeaceus*-type. Four Cerealia-type grains also occur and 5 grains do not fit any category. A number of wild grass species are included within each of these categories and the identifications provide little additional insight to those based upon the key of Andersen. The grains that do not fit any category (GM-2, GM-9, GM-13, RBO-9 and RBO-13) all have pores exceeding 3 µm in diameter and non-protruding annuli with sharp outer boundaries. The classification system requires that grains with pores of 4 µm diameter or above have either diffuse-edged, non-protruding annuli or sharp-edged protruding annuli (Table 5.8). As annulus boundary type is a subjective measurement it may be that the characteristic has been incorrectly identified in these grains and if so, then this shows the potential problem of incorporating subjective measurements into a key. An alternative possibility is that the identifications are correct and that some grains have non-protruding annuli with sharp outer boundaries.

The species groupings suggested by the two keys only overlap in 12 out of the 45 cases, suggesting that a large discrepancy exists between the two approaches. This is primarily due to the identification of 27 Small Poaceae-type grains using the method of Küster, a group which shows no species overlap with either the *Hordeum* or *Avena-Triticum* groups of Andersen. This problem is addressed in detail in section 5.3.2. There is a relatively high level of overlap between the groups suggested for the remaining 18 grains (12 out of 18 identifications overlap), however, which is encouraging.

5.3.1.2 Group 2 (*ca* 8050-6800 BP)

Large grass grains are present in the three study sites containing records spanning this period (Cess Dell, Gilderson Marr and The Bog at Roos). The grains all occur during and immediately after the initial *Alnus glutinosa* expansions within the site catchments (chapters 6, 7 and 9), with the exception of GM-17, and the ages of the grains mean that it is highly unlikely that they originate from domesticated taxa.

Of the 16 grains located (see Table 5.2), 7 belong to Andersen's (1979) *Hordeum* group, 5 to his *Avena-Triticum* group and 4 grains do not fit any of his categories. As discussed above for group A, the wetland genus *Glyceria* is contained within the *Hordeum* group and it is possible that the grains in this group could originate from this genus. Although a number of disturbed ground taxa are also included in the *Hordeum* group (Tables 5.7 and 5.10), there is little evidence for significant disturbance within the catchments of Cess Dell and The Bog at Roos (sections 6.5 and 9.5) and it is perhaps unlikely that the large grass pollen is reflecting incidences of these species (although localised disturbances due to treefall for example would have occurred). Disturbed ground grasses are more likely to have contributed to the pollen record at Gilderson Marr, however (section 7.5). The *Avena-Triticum* group grains are all from the Gilderson Marr profile (Table 5.4) and several are very large, having mean grains sizes of 50-59 µm and annulus diameters of 14-17 µm (GM-18, GM-19 and GM-22). Grain GM-24, although slightly smaller, also has a large annulus diameter of 14 µm. On the basis of Andersen's Table 3 (*ibid*) these grains should all belong to the genus *Triticum*, with no other taxa within his study having an annulus diameter of >13 µm. The ages of the grains make this extremely unlikely and it is clear that at least one wild taxon can produce *Triticum*-type pollen. This statement refines the above comment (Group 1 results) that wild taxa are capable of producing *Avena-Triticum* group pollen. Other early occurrences of *Triticum*-type grains have been noted from the North York Moors by Innes (1990). A comprehensive modern pollen study would be of help in identifying possible wild taxa that these grains could originate from.

The grains that do not fit Andersen's group fall into two categories and provide further evidence of grain and/or annulus size overlap between his groups. Grains GM-23 and GM-26 have *Avena-Triticum* group annulus sizes, but *Hordeum* group grain sizes (annulus diameters of 12 µm and 11 µm and mean grain sizes of 39.5 µm and 34.5 µm, respectively), whilst grains CD-7 and RBO-23 have *Hordeum* group annulus sizes, but *Avena-Triticum* group grain sizes (annulus diameters of 10 µm and mean grain sizes of 51.5 µm and 45.5 µm).

Several Küster categories are covered by the grains. Eight grains are identified as Small Poaceae-type, 3 as *Glyceria*-type, 3 as Cerealia-type and 2 do not fit his data. The two grains that do not fit his data both have incorrect annulus types (grain GM-20 has a diffuse-edged, protruding annulus and grain GM-22 has a sharp-edged, non-protruding annulus). As discussed above for group A, it is possible that this is due to the incorrect assignment of annulus boundary type.

When the results of the two keys are compared, only 4 out of the 16 suggested species lists overlap. The bulk of this discrepancy is due to the identification of 8 Small Poaceae-type grains using the key of Küster (see group 1 results for explanation). The other 4 identifications that are not in agreement arise because the data do not fit one of the keys, the results for these instances are consequently not comparable.

5.3.1.3 Group 3 (*ca* 6100-2000 BP)

The profiles from Cess Dell, Gilderson Marr and The Bog at Roos all cover part of this period (chapters 6, 7 and 9). As discussed in Table 5.9 this group includes grains dating from the Neolithic Period and the Bronze and Iron Ages, and unlike the previous two groups potentially contains pollen originating from cultivated cereals. Large grass grains occurring <1000 ^{14}C yr prior to the traditional elm decline (*ca* 5100 BP) are also included within this group following suggestions that small-scale cultivation may have been occurring during this time (e.g. Edwards and Hirons, 1984; Edwards, 1998).

Of the 86 grains contained within this group (see Table 5.2), 43 belong to Andersen's *Hordeum* group and 32 to his *Avena-Triticum* group. Three *Secale cereale* grains also occur and 8 grains do not fit his data. Interpretation of the grains within this group is more difficult than in the preceding groups as input from domesticated species cannot be ruled out. The grains within the *Hordeum* group could reflect incidences of wild grasses, *Hordeum vulgare* or *Triticum monococcum*, but conclusions cannot be more precise. Although *Avena fatua* is the only wild grass contained within Andersen's *Avena-Triticum* group (Table 5.7), the observation that other wild grasses are capable of producing pollen with similar characteristics (see above) means that conclusions must also remain tentative for this group. The interpretation of grains from these two pollen types is discussed in detail in the relevant results chapters. Identification of the three *Secale cereale* grains (RBO-60, RBO-66 and RBO-70) is more secure. The grains not fitting any of Andersen's groups all have annulus sizes consistent with the *Avena-Triticum* group, but mean grain sizes that place them within the *Hordeum* group.

All of the Küster types (excluding *Zea mays*) are represented, with 49 Small Poaceae-type, 21 Cerealia-type, 3 *Bromus hordeaceus*-type, 2 *Glyceria*-type and 1 *Arrhenaterum*-type grain identified. These identifications suggest that a large number of Poaceae species may have contributed to the pollen records of the three sites during this period. This is to be expected, given that a number of widely different vegetational environments (ranging from dense woodland and fen carr to almost completely deforested landscapes) are suggested to have existed within the site catchments during this period. It is perhaps surprising that all of the pollen types are also represented in group A, however, when vegetational environments were more uniform.

Ten grains do not fit any of the Küster pollen types. Of these ten, nine have sharp-edged, but non-protruding annuli and the other (GM-37) has a *Glyceria*-type annulus to pore ratio, but a sharp-edged, protruding pore that is not consistent with the group. Whilst the former nine grains may represent mis-identifications due to analyst error, it is hard to see how a similar explanation could account for the latter grain as the key attributes are objective measurements.

Only 24 of the 86 species groups suggested by the two keys overlap (Tables 6.3-6.6). Of the 62 identifications that do not agree, 49 are grains identified as Small Poaceae-type according to Küster, and 10 reflect grains which do not fit any groups of one key.

5.3.1.4 Group 4 (*ca* 2000 BP-present)

Group 4 includes pollen dating to the Roman and Historical Periods and is covered by the profiles from The Bog at Roos and Sproatley Bog. It is likely that this group contains grains originating from both wild and domesticated taxa.

A total of 389 grains are contained within group 4 (see Table 5.2), with 112 grains identified as Andersen's *Hordeum* group, 118 as his *Avena-Triticum* group and 128 as *Secale cereale.* As discussed above for group 3, it is not possible to say with certainty on the basis of Andersen's data whether the grains contained within the *Hordeum* and *Avena-Triticum* groups originate from wild or cultivated taxa. Given the large number of *Secale cereale* grains and the wider palynological evidence for agriculture within the site catchments (particularly at Sproatley Bog; chapters 8 and 9), it is likely that a large proportion of these grains originate from domesticated taxa.

A total of 31 grains do not fit any of Andersen's categories. Of these, 26 have annulus diameters consistent with the *Avena-Triticum* group, but mean grain sizes that place them within the *Hordeum* group. The remaining 5 grains have *Avena-Triticum* group mean grain sizes, but *Hordeum* group annulus diameters. As previously suggested for groups 1 and 2, the data obtained during this study provide clear evidence for grain size and/or annulus diameter overlap between Andersen's *Hordeum* and *Avena-Triticum* groups. Whether this overlap would still be evident if the pollen grains located during this study were standardised for grain size (by comparison with *Corylus avellana* pollen) is uncertain.

All of the European Küster types are represented by the data, with 141 grains identified as Small Poaceae-type, 163 as Cerealia-type, 31 as *Arrhenaterum*-type, 12 as *Bromus hordeaceus*-type and 4 as *Glyceria*-type. A total of 38 grains do not fit any category. The proportion of pollen identified as Cerealia-type is considerably higher than in any of the other three groups, and whilst four wild taxa are included within this type, two of these are frequent arable weeds (*Elymus caninus* and *Avena fatua*; Table 5.10) and it is possible that much of the pollen is reflecting arable activity. Given the presence of Cerealia-type pollen throughout the Holocene, conclusions based upon the Küster types must also remain tentative.

Thirty-eight grains do not fit any of the Küster pollen types. Of these 18 have a *Glyceria*-type annulus to pore ratio, but a sharp-edged, protruding pore that is not consistent with the group. The remainder have annulus to pore ratios and pore diameters consistent with the *Bromus-hordeaceus*- and Cerealia-types, but the incorrect annulus form (17 have sharp-edged non-protruding annuli and 4 have diffuse-edged, protruding annuli).

184 of the 389 species groups suggested by the two keys overlap (Tables 6.3-6.6). Of the 205 identifications that do not agree, 141 are grains identified as Small Poaceae-type according to Küster, and 38 reflect grains which do not fit any groups of one key.

As a general conclusion, there is greater agreement between the two keys for time periods 3 and 4 than for time periods 1 and 2, and for the Sproatley Bog data than for the other sites (although this may be a reflection of the large proportion of group 4 grains from the site; see Table 5.5).

5.3.2 A combined approach?

Whilst identification of large Poaceae grains using the key of Küster provides little additional information to the method of Andersen (frequently increasing the list of possible species; see above), the potential exists to refine species lists by combining the two approaches. The following discussion is speculative and is intended to highlight and assess possible directions for future work. More secure conclusions would require a comprehensive modern pollen study.

The *Hordeum* group of Andersen (1979) contains nine wild taxa that cannot be reliably separated on the basis of his data from the domesticated species *Hordeum vulgare* and *Triticum monococcum* (Table 5.7). This poses a number of interpretational problems, particularly as the wetland taxa *Glyceria fluitans* and *G. plicata* are contained within the group and may be expected to grow naturally in the proximity of many pollen sites. If the cultivated taxa could be separated from the wild species contained within this group, more positive inferences could me made. On the basis of annulus and pore characteristics the taxa contained within Andersen's *Hordeum* group are separated into four distinct types in Küster's (1988) study (Table 5.8). The potential thus exists to split the *Hordeum* group using the measurements of Küster and, hence, to decrease the number of possible species that a grain could originate from by combining the two approaches (see Table 5.11).

There are a number of potential problems relating to such a combined approach, most of which are highlighted by the data obtained during this study. Firstly, a number of grains do not fit the characteristics of the keys, suggesting that a degree of overlap exists between the types of both Andersen (1979) and Küster (1988). Secondly, 10 species included within the study of Küster were not analysed by Andersen and may also fall within his *Hordeum* group, but this cannot be determined from the available data (see Table 5.12). Finally, the combination of the two keys is hampered by the incorporation of many *Hordeum* group grains within the Small Poaceae-type of Küster, due to differences in the size constraints used by the two authors. It is clear from the data of Andersen that many of the species indicated as having grain sizes >40 µm by Küster (including most of Andersen's *Hordeum* group) can be considerably smaller. This suggests that a significant level of variation in grain size occurs in some species. The size constraint of >40 µm has consequently been ignored in the following discussion, although whether the type characteristics used by Küster hold for grains of <40 µm is uncertain. Characters such as the ratio between pore and annulus diameter, along with annulus protrusion and boundary type should still hold as they are relative measures, but actual pore diameters may differ. As an example it may be expected to encounter more grains with pore diameters of <4 µm purely as a function of overall smaller grain sizes. This would potentially increase the number of *Arrhenaterum*-type grains (i.e. *Elymus repens* using the combined approach), a type distinguished by Küster from other large grasses by its small pore size (Table 5.11).

In order to investigate the potential of this approach, grains identified during this study as belonging to Andersen's *Hordeum* group were split into species groups according to the criteria stated in Table 5.11. Identification of the species groups depends upon whether annulus diameter to pore diameter ratios of 2.0 were classed as <2 or >2 by Küster (1988). If the first approach was adopted then all grains in group 1 (*ca* 10,100-9600 BP) originate from species groups A and B, so could be from *Elymus repens,* other *Elymus* species, *Glyceria fluitans* or *G. plicata* - all ecologically feasible taxa. If the second approach was used, then some of the grains may also have originated from *Bromus inermis* (species group C). Where data are available, a similar list of possible taxa is seen for all study sites. Grains from group 2 (*ca* 8100-6800 BP) are also suggested to have originated from wild taxa, with the grains primarily being placed in species group A (*Elymus, Glyceria fluitans, G. plicata*) or species group C (*Bromus inermis*) depending upon how annulus diameter to pore diameter ratios of 2.0 were assigned by Küster. The data thus suggest that all of the *Hordeum* group grains within groups 1 and 2 originated from wild taxa, which is encouraging given the ages of the deposits in which they were located.

Grains from time period 3 comprise a mixture of species groups. At Gilderson Marr, species groups A or C and species group D are represented. Species group D includes the domesticated taxa *Hordeum vulgare* and *Triticum monococcum* and the wild taxon *Hordeum murinum* (a plant of disturbed ground), so it is possible that a number of the *Hordeum* group grains may indicate arable cultivation. At Cess Dell all species groups are represented, whilst at The Bog at Roos grains mostly originate from species group B, although odd grains from species groups A, C and D also occur. This may suggest that most *Hordeum* group grains from The Bog at Roos originated from *Glyceria maxima* or *Elymus repens.*

Time period 4 is covered by the profiles from The Bog at Roos and Sproatley Bog. At The Bog at Roos, all species groups are represented, but most grains originate from species group B (*Elymus repens* and *Glyceria maxima*) and are subsequently likely to originate from wild taxa. At Sproatley Bog 37 out of the 73 *Hordeum* group grains are from species group D so could originate from cultivated taxa, with the remaining grains covering the other three species groups.

The results of the combined approach thus suggest that the *Hordeum* group grains from within groups 3 and 4 may be comprised of a mixture of potentially cultivated and wild taxa.

The problems outlined above mean that further work would need to be undertaken before any firm conclusions regarding the value of such a combined approach could be made. It is perhaps worrying that several potential species groups are seen at most sites in all age groups, especially given that there is evidence for overlap between the Küster characteristics incorporated in the method (see 5.3.1). It is encouraging though that species groups containing cultivated taxa are only seen in age groups 3 and 4 (i.e. after the hypothesised onset of arable farming within Britain; see Table 5.9). It would be of less value to use such an approach to attempt to split the *Avena-Triticum* group of

Andersen, although more secure inferences may result if a grain also belongs to the Cerealia-type of Küster (although this would still not provide conclusive proof that the grain belonged to a cultivated taxon).

5.3.3 Multivariate analyses

5.3.3.1 Principal component analysis (PCA): theoretical background

PCA is an exploratory technique that can produce 2- or 3-dimensional representations of multivariate data and can show structure within the dataset (e.g. grouping of samples) that is not always obvious to the naked eye (Baxter, 1994). It is one of the most frequently used ordination techniques in palynology (Prentice, 1980) and involves the eigenanalysis of a covariance or correlation matrix calculated from the original data. In general, a correlation matrix is produced if the variables have been measured on different scales and require standardising, or to emphasise rarer taxa. In most other situations a covariance matrix is preferred (Maddy and Brew, 1995). In essence a series of linear transformations are carried out on the multi-dimensional data by eigenanalysis, and new axes are produced that describe as much of the variation within the dataset as possible. These are termed principal components. The first component is the axis that accounts for the highest proportion of the variance, the second component accounts for the highest possible proportion of the remaining variance (but must be uncorrelated with the first component) and so on. Whilst it is possible to produce as many axes of variation as there are variables, the bulk of the variance is generally accounted for by the first few principal components, with the relative amount of the total variability accounted for by each axis shown as an eigenvalue. The original samples are assigned component scores for each axis and scatterplots of the sample scores in relation to the principal component axes can subsequently be plotted. By comparing the proximities of samples to one another on these plots, associations between the samples can be explored.

Complete descriptions and evaluations of the technique may be found in Prentice (1980), Baxter (1994) and Maddy and Brew (1995).

5.3.3.2 Principal component analysis: results and discussion

PCA was used in this study to investigate if any grouping of the large Poaceae pollen located during laboratory analysis was evident when different combinations of variables were considered. Calculations were performed using Minitab v.13 by Dr N. Fieller and all of the grains presented in Tables 5.3-5.6 were included in the analyses.

(i) PCA: general results

PCA were carried out using three variable combinations in order to assess how variation in the attributes considered affected separation of the unconstrained data. Full details of the variable combinations and the codes used in the following text are presented in Table 5.13. The following discussions summarise the results of the three PCA analyses.

PCA-a essentially incorporates the variables used by Andersen to define his Poaceae pollen groups, although both the length of the longest grain axis and the length of the axis at 90° to this were included rather than mean grain size. This was done as it represents a more flexible combination of variables (N. Fieller, pers. comm.). The eigenanalysis (Table 5.14) shows that the first two principal components (PCs) account for 89.8 % of the variation and that plots of these two components are likely to be very successful in summarising the data. The first PC is dominated by overall grain size and the second PC by pollen index (i.e. pollen shape).

PCA-b includes the same combination of variables with the addition of attributes F (pore diameter) and G (the ratio of the annulus diameter to pore diameter). As such the analysis combines the attributes of Andersen with two of those used by Küster (i.e. F and G). The eigenanalysis (Table 5.15) suggests that the first three PCs account for 91.9 % of the variation within the data. PC-1b is dominated by the overall grain size, PC-2b by the pollen index and PC-3b is mostly related to the annulus diameter to pore diameter ratio.

Finally, PCA-c includes the same variables as PCA-b with the addition of attributes H (annulus protrusion) and I (outer annulus boundary form). This analysis subsequently incorporates all of the grain attributes used in the keys of both Andersen and Küster. The validity of including attributes H and I is uncertain, as unlike the other attributes both are effectively 'yes/no' variables (N. Fieller, pers. comm.). The results of the eigenanalysis show that the first four PCs account for 88.7 % of the sample variation. PCs 1c-3c are dominated by similar attributes to PCs 1b-3b (see above) and PC-4c is mostly related to annulus protrusion and annulus outer boundary form, with grains with sharp, protruding annuli having high scores.

The results thus suggest that it is possible to summarise the majority of the variability within the dataset into 2-4 axes of variation depending upon which variables are included within the analysis. When the sample data are plotted against combinations of these PCs, little separation is obvious (the data appearing as a swarm; plots not presented), however, when age groups, or Andersen or Küster identifications of the samples are also shown on the plots, a number of patterns emerge within the data. The results of the PCA are discussed in relation to these factors in the following sections.

(ii) Separation of the sample data by Andersen groups

PCA-a incorporates the attributes used within the key of Andersen, and a plot of the sample data (labelled by Andersen type) against the first two PCs of the analysis is presented in Figure 5.1. The grouping evident within the data is essentially reflecting variation in overall grain size (both grain diameter and annulus size; y-axis) and grain shape (pollen index; x-axis). Grains identified as *Secale cereale* are shown to the left and the less prolate *Hordeum* group and *Avena-Triticum* group grains towards the right of the plot. The larger *Avena-Triticum* grains are plotted above the smaller *Hordeum* group grains. Separation of the three pollen groups is generally good with each pollen type forming a distinct group on the plot. There is a degree of overlap between the *Avena-Triticum* and *Hordeum* groups though which supports the conclusions of section 5.3.1. Many of the grains not fitting the data of Andersen (labelled 'nofit' on the plot) are positioned within this overlap, although interestingly a number are also located throughout the cluster of *Hordeum* group grains, suggesting that they may originate from this group. This is supported by the results of the discriminant analyses (section 5.3.3.4). Separation of *Secale cereale* from grains belonging to the *Avena-Triticum* group is good, but there is a slight overlap with the *Hordeum* group grains.

As expected from the results of the eigenanalysis (Table 5.14), separation of the groups is less clear when the data are plotted against the second (PC-2a) and third (PC-3a) principal components (Figure 5.2).

The groupings discussed above remain evident when the sample scores are plotted against the first and second PCs of analysis PCA-b (Figure 5.3). Overlap between the three groups is greater (cf. PCA-a) though which suggests that the incorporation of pore diameter and annulus diameter to pore diameter data reduces the separability of the Andersen types. This may be expected as the attributes do not form part of his key. Even greater overlap is evident when annulus protrusion and outer boundary form data are also incorporated (PCA-c), as shown by Figure 5.4.

Overlap between the *Avena-Triticum* and *Hordeum* groups is almost complete (and overlap of the two groups with *Secale cereale* much higher) when the sample scores are plotted against the second, third and fourth components of PCA-b and PCA-c (e.g. Figure 5.5; other data not presented), again suggesting that the first two components are most successful in separating the sample data when it is labelled according to Andersen group.

(iii) Separation of the sample data by Küster groups

Although there is overlap between types when the data are labelled according to Küster type and plotted in relation to PCs 1a and 2a, several groupings are evident (Figure 5.6). The small Poaceae-type grains are located towards the base of the plot (small grain size shows as a low y-axis value) and Cerealia-type grains in the mid- to upper part of the plot. *Arrhenaterum*-type, *Bromus hordeaceus*-type and *Glyceria*-type grains are generally located within, and close to, the overlap of the small Poaceae-type and Cerealia-type distributions. Grains not fitting the data are scattered throughout the plot. A number of the *Arrhenaterum*-type grains occur amongst the Cerealia-type grains towards the left of the plot. Consideration of grain form and pore location indicates that these grains probably originate from *Secale cereale,* suggesting that the key of Küster does not hold for some grains of this species. The failure of PCA-a to clearly separate the types is perhaps to be expected given that the key of Küster is based upon a suite of attributes not included in the analysis, but it is clear that the larger grains (located towards the top of the plot) tend to be identified as possibly originating from cultivated taxa.

There is little improvement in terms of separation of the Küster types when pore diameter and annulus diameter to pore diameter ratios are included within the analysis (PCA-b; Figure 5.7), and separation of the *Arrhenaterum*-type, *Bromus hordeaceus*-type and *Glyceria*-type grains remains difficult. When all of the attributes used in the key of Küster are incorporated (PCA-c), grouping is more obvious (Figure 5.8). The Cerealia-type grains form a tighter cluster towards the top right of the plot, which only overlaps slightly with the spread of Small Poaceae-type grains across the lower part of the plot. *Glyceria*-type and *Bromus hordeaceus*-type grains are mostly (but not all) grouped together towards the far left of the plot, with the distributions of the two types overlapping that of the Small Poaceae-type. *Arrhenaterum*-type grains are scattered within the central and right-hand parts of the Small Poaceae-type distribution. Grains not fitting the key occur throughout much of the plot, but are absent from the lower part of the Small Poaceae-type distribution.

As a general conclusion, the Küster groups are most clearly separable when all of the attribute data is included, perhaps as expected, although reasonable separation of the Cerealia- and Small Poaceae-types is possible when only the attributes used in the Andersen key are used. As for the Andersen data, separation of the groups is less clear when the data are plotted against the second (PC-2a/2b/2c) and third (PC-3a/3b/3c) principal components (e.g. Figures 5.8-5.10).

When the locations of the Küster types are compared to those of the Andersen types (discussed above) for the plot of PC-1a vs PC 2a (Figures 5.1 and 5.6), a number of points can be made. Firstly, the grains not fitting the key of Küster (Figure 5.6) are mostly located amongst the *Avena-Triticum* group on the plot labelled according to

Andersen types (Figure 5.1). Secondly, a large proportion of the grains identified as belonging to the *Avena-Triticum* group are also identified as Cerealia-type. Finally, a number of the grains identified as *Arrhenaterum*-type, *Bromus hordeaceus*-type and *Glyceria*-type (Figure 5.6) are located within or close to the area of overlap between the *Hordeum* and *Avena-Triticum* groups of Andersen (Figure 5.1).

(ii) Separation of the sample data by age groups

In order to investigate whether the data were separable by age group (i.e. if there was any grouping of the data from different time periods), the samples were labelled according to the age groups defined in Table 5.9 and plotted against the first two PCs of each analysis (Figures 5.11-5.13). There is some evidence for grouping of the data in the plot of PC-1a against PC-2a (Figure 5.11). Grains from age group 4 are spread across the plot, with the grains to the left of the distribution having high pollen indices and likely to originate from *Secale cereale.* The observation that grains from this group are more widely spread than those from the others age groups is likely to reflect a combination of the presence of grains identifiable as *Secale cereale,* the variety of pollen types identified within the group and the overall higher sample size (cf. groups 1-3). If grains with PC-2a values of <-1 (prolate grains cf. *Secale cereale*) are ignored, some separation of grains lying towards the right of the plot is evident. The larger grains (high PC-1a values) are generally from groups 3 and 4, although several group 2 grains are also present towards the top of the plot (the larger group two grains are all from Gilderson Marr). The bulk of the group 1 and 2 grains are clustered towards the bottom-right of the plot indicating that the pre-agricultural grains are mostly small with low pollen indexes. This is interesting as excluding the grains from Gilderson Marr (discussed above) all of the larger grains are from deposits that post-date the onset of arable farming in Britain.

5.3.3.3 Discriminant analysis (DA): theoretical background

Discriminant analysis (DA) assumes that known groups exist in the data and that all of these groups are represented by the dataset (Baxter, 1994). The technique then calculates linear combinations of variables that separate the groups as clearly as possible. That is to say the technique splits the (multivariate) space occupied by the data into regions, with each region containing a distinct group (Baxter, 1994). It is not always possible to separate the data perfectly and some individuals may lie within the wrong region and hence be mis-classified. By quantifying the proportions of samples that are mis-classified, the success of the partitioning of the data (i.e. discrimination) can be assessed. High levels of mis-classification may suggest that the groups upon which the analysis is based are indistinct. On the basis of these calculations it is then possible to predict which group an 'unknown' individual is most likely to originate from.

There are two main forms of discriminant function (linear and quadratic) and the type used is largely dependent upon the sample size and population characteristics of the dataset. Quadratic discrimination requires a larger number of samples within each group than linear discrimination and that the data are normally distributed. The data need not be normally distributed within groups for linear discrimination to be valid (although this is preferable), which in combination with the tolerance of the approach to low sample sizes, makes the method more flexible than quadratic discrimination.

5.3.3.4 Discriminant analysis: results and discussion

In this study linear DA was used to assess the separability of the Andersen (1979) Poaceae groups and to predict which groups the grains not fitting his data were most likely to belong to. The analysis was also carried out as a check on the groupings suggested by the PCA. DA was performed on all grains identified as belonging to *Secale cereale* or the *Hordeum* and *Avena-Triticum* groups. The probabilities that grains not fitting his data belonged to each of these groups were then calculated, and the group that each grain was most likely to have originated from predicted.

Calculations were performed using Minitab v.13 by Dr N. Fieller. All grains were included in the analysis except those identified as HG* and ATG* in Tables 5.3-5.6. These grains were interpreted as being mechanically distorted (see above), with the differences between the two grain sizes and the high pollen indexes subsequently artificial and hence likely to confuse interpretation of the analysis. Attributes A, B, D, E, F and G (see Table 5.1 for explanation) were included within the analysis. Annulus protrusion and annulus boundary form were excluded as the attributes are effectively yes/no characteristics and the validity of including this form of data is uncertain (N. Fieller, pers. comm.). The results of the PCA indicate that the inclusion of this data produces little additional information in any case.

Table 5.17 shows the success of the discriminant functions in separating the grains identified as belonging to each of the Andersen groups discussed above. The functions were very successful and correctly assigned 93 % of the grains to the relevant Andersen group. Discrimination of the *Hordeum* group was particularly successful, with 96.7 % of the grains identified in the laboratory as belonging to this group correctly assigned. This suggests that the three Andersen groups are distinct on the basis of the attributes included within the analysis.

The predicted groups of the grains not fitting Andersen's characteristics (i.e. 'unknown' grains) are presented in Table 5.18. The analyses predicted that the majority of the grains were likely to belong to the *Hordeum* group (41 out of the 48 unknown grains), with 6 likely to belong to the *Avena-Triticum* group, and 1 identified as *Secale cereale.* The probability that each grain belongs to its predicted group is generally high at *ca* 0.6-0.9, indicating that the assignments are relatively reliable. Classification of several grains is less certain though, suggesting that it is not possible to confidently predict the probable groups of all grains. For example, there is a probability of 0.464 that grain GM-23 belongs to the *Avena-Triticum* group, but a probability of 0.430 that it belongs to the *Hordeum* group.

The DA is essentially reflecting the locations of the unknown grains on the PCA plot that is based upon a similar suite of attributes (Figure 5.3), with the grains predicted as belonging to the *Hordeum* group located within the area occupied by the *Hordeum* group grains on the plot. The grain predicted as originating from *Secale cereale* is a distorted *Hordeum* group or *Avena-Triticum* group grain, but the pollen index was not quite high enough for the grain to be classified as HG* or ATG* (the grain had an index of 1.24 cf. >1.26). It is thus likely that artificial distortion of the grain resulted in the prediction that it originated from *Secale cereale.* If this grain is ignored then the data suggest that there is overlap between the Andersen characteristics of the *Hordeum* and

Avena-Triticum groups, but not between these groups and *Secale cereale.* This is in agreement with the conclusions of the laboratory analyses presented in section 5.3.1 and the results of the PCA (Figures 5.1, 5.3 and 5.4). The successes of the DA suggest that the technique may be used to predict the Andersen groups of grains that do not fit his data (i.e. that fall within the overlap between the *Hordeum* and *Avena-Triticum* groups) in cases where a large enough sample of grains is available.

5.4 Conclusions and classification system used in this study

5.4.1 Conclusions

(i) Pollen keys

a) The key of Andersen (1979) was largely successful in assigning large Poaceae pollen to types, but a number of grains did not fit the characteristics of any of the species groups. This suggests that a degree of overlap exists between the characteristics of at least two of the groups included within the key. On the basis of the laboratory analysis, PCA and DA it may be suggested that overlap exists between the characteristics of the *Hordeum* and *Avena-Triticum* groups.

b) A number of grains that clearly pre-date the hypothesised onset of arable agriculture within Britain were identified as belonging to Andersen's *Avena-Triticum* group. If *Avena fatua* was indeed absent from England prior to the Iron Age (cf. Godwin, 1975; Dickson, 1988) then this suggests that at least one other wild species is capable of producing *Avena-Triticum* type pollen.

c) Although Andersen's Table 3 (1979) suggests that grains with annulus diameters of >13 µm are likely to originate from the genus *Triticum*, the presence of grains with similar characteristics in deposits pre-dating *ca* 7000 BP indicates that a wild taxon (or wild taxa) can produce *Triticum*-type pollen.

d) The key of Küster (1988) was also largely successful in assigning large Poaceae pollen to types, although a degree of overlap between the characteristics of at least two of these types is again suggested (although how much this reflects analyst error in assigning annulus boundary form is uncertain).

e) When grains identified as Small Poaceae-type in the key of Küster and grains not fitting any of the groups of one key are ignored, there is generally good agreement between the identifications suggested by the two keys. This is at least partially a reflection of the large number of species within the *Hordeum* group of Andersen.
f) There is greater agreement between the identifications of the two keys for age groups 3 and 4 (post-6100 BP) than for age groups 1 and 2 (pre-6100 BP).
g) It is not possible to reliably separate the pollen of wild Poaceae taxa from that of domesticated species (except perhaps *Secale cereale*) using either key.

(ii) Combination of the keys

Although the above comments need to be taken into account, by combining the characteristics used by Andersen with those used by Küster it may be possible to separate the pollen of *Hordeum vulgare* and *Triticum monococcum* from the other wild taxa contained within Andersen's *Hordeum* group excluding *Hordeum murinum*. Whilst speculative, the results are encouraging with pollen from the species group containing the two cultivated taxa only identified in age groups 3 and 4. Further evaluation of the validity of the technique would require a comprehensive modern pollen study.

(iii) Multivariate analyses

a) Although simple bivariate scatter plots generally showed no obvious patterns (data not presented), the results of the PCA provided a great deal of information concerning structure within the data. The technique successfully summarised the variation observed within the data into 2-4 axes, depending upon which combinations of variables were included within the analysis. The first and second PCs (dominated by overall grain size and grain shape, respectively) were most successful in separating the various groups.
b) Although distinct groups were evident within the data, the results of the PCA supported the observation that a degree of overlap exists between the *Avena-Triticum* and *Hordeum* groups of Andersen.
c) Separation of the Küster pollen types by PCA was less clear (cf. the Andersen groups), although Cerealia-type pollen was largely separable from the other types. The distributions of the *Glyceria-*, *Arrhenaterum-* and *Bromus hordeaceus*-types overlapped those of at least one other type. Interestingly, a number of grains from these three pollen

types were located within, or close to, the area of overlap between Andersen's *Avena-Triticum* and *Hordeum* groups.

d) The results of the PCA also suggest that the majority of the larger grains (in terms of both grain size and annulus diameter) originated from age groups 3 and 4 (i.e. deposits post-dating the onset of arable agriculture in Britain).

e) It is possible to suggest which group a grain not fitting a key is likely to belong to on the basis of its location on the PCA plot, however, DA represents a more reliable approach. DA successfully distinguished between the various Andersen groups and was useful in predicting the group from which grains not fitting the key were most likely to have originated from. It is probable that most of the grains not fitting Andersen's key could be placed within the *Hordeum* group. If a large enough sample size is available, DA thus represents a useful technique for classifying grains with intermediate pollen characteristics.

5.4.2 Classification adopted in this study

In chapters 6-10, interpretation of the large Poaceae pollen record is based upon the identifications assigned to the grains using the keys of both Andersen (1979) and Küster (1988; presented in Tables 5.3-5.6), and by consideration of the wider palaeoecological record. Where appropriate, reference is also made to the results of the combined approach (section 5.3.2).

The large number of categories contained within the keys of Andersen (1979) and Küster (1988) made it impractical to include the identifications suggested by each key within the pollen diagrams presented. Instead, all large Poaceae pollen located during this study has been presented in the diagrams as either *Secale cereale*-type or Poaceae >37 µm (see below). It should be stressed that this classification system has been employed purely for ease of presentation and does not negate the results of this chapter. Details of the two categories are given below:

(i) *Secale cereale*-type: This includes all grains having a pollen index of >1.26 (i.e. prolate grains) and an eccentrically positioned pore, and combines the data of Beug (1961) and Andersen (1979). Whilst it is likely that the grains originate predominately from *Secale*, it is possible that undomesticated taxa are also capable of producing occasional grains of this type (O'Connell *et al.*, 1999).

(ii) Poaceae >37 µm: This category includes all other large Poaceae grains (i.e. other grass pollen having a grain size of >37 µm).

Chapter 6: Cess Dell: results and discussion

6.1 Introduction

This chapter presents the results of the analysis of the core obtained from Cess Dell. The core is described and the results of the radiocarbon dating programme analysed in sections 6.2 and 6.3. Pollen analytical results are introduced and described in section 6.4, with damaged pollen and local pollen assemblage zones being suggested. Finally, the vegetational development of the catchment is discussed in detail in section 6.5.

6.2 Core description

A detailed description of the core obtained is given in Table 6.1. From the results of the pollen analyses and radiocarbon dating programme (see below), it is evident that the deposits cover at least part of the Late-Glacial and approximately the first five millennia of the Holocene. As the core was not bottomed it is possible that the site contains a more complete Late-Glacial sequence than was recovered. The section between 436 cm and 76 cm was sampled for pollen and associated analyses.

6.3 Radiocarbon dating

A total of nine AMS radiocarbon dates were obtained for the profile, with full details being given in Appendix 6. Whilst dates AA-30870 to AA-30876 seem reasonable, it is clear that the accuracies of dates AA-30869 and AA-30877 are less certain. The date of 9490±70 BP (AA-30870; 391.5-393.5 cm depth) obtained for deposits at the base of the sustained *Corylus avellana*-type rise compares favourably with dates obtained for a similar event at the other three study sites. This suggests that date AA-30877 (9360±70 BP [AA-30877]) is too young. As such, although the date is presented alongside the pollen diagrams provided (Figures 6.2-6.9 and 6.11-6.18), it has been excluded from any interpolations and ignored in the calculation of accumulation rates. The second date of concern, AA-30869 (10,440±95 BP), corresponds to the earliest *Betula* maximum. Interpolating back from this date gives an age of *ca* 10,740 BP for the lowermost organic deposits, which seem to be of early Holocene date on palynological grounds. This suggests that the date is too old, perhaps due to the inwashing of older material. This date has subsequently also been ignored in any interpolations. Instead it was decided to fit a trendline to the preceding dates using linear regression and to extrapolate this curve to the base of the organic sequence. When the regression line is based upon dates AA-30870 to AA-30873 an interpolated age of *ca* 10,400 BP is obtained for the lowermost organic deposits. A regression line based solely upon dates AA-30870 and AA-30871 gives a corresponding date of *ca* 10,050 BP (see Figure 6.1). Whilst neither method is ideal, the latter age is what might be anticipated. An age of 10,050 BP was subsequently assigned to the earliest organic deposit (434 cm) and used when calculating accumulation rates. Any accumulation rates and interpolated ages for samples associated with sediments below 393.5 cm depth should therefore be treated cautiously, particularly given the presence of radiocarbon plateaux at *ca* 10,000-9900 BP and 9600-9500 BP (Kromer and Becker, 1993).

A time-depth curve of uncalibrated and calibrated BP dates is given in Figure 6.1. This suggests relatively even sediment accumulation rates within the gyttja and peat units, with the accumulation rate in the peat deposits being comparatively greater than within the gyttja.

6.4 Pollen data

Local deteriorated pollen assemblage zones (LDPAZs) are prefixed by the initials CDDET and local pollen assemblage zones (LPAZs) by the initials CD. Both zone types are numbered from the bottom up, and to avoid confusion LPAZs are labelled numerically and LDPAZs alphabetically.

6.4.1 Deteriorated pollen analysis

6.4.1.1 Local deteriorated pollen assemblage zones (LDPAZs)

A diagram showing total pollen preservation is presented in Figure 6.2, whilst a series of diagrams showing the preservation characteristics of the major pollen types is given in Figures 6.3-6.9. Total deterioration percentages are based upon the sum of TLP (including *Alnus*). Details of the LDPAZs assigned are given in Table 6.2, and a DCA plot of the average LDPAZ and deterioration type scores for the first two axes of the ordination is presented in Figure 6.10.

a) CDDET-A: 436-421 cm; *ca* 10,050-9860 BP (*ca* 11,520-11,240 cal BP)

Pollen preservation is good throughout the zone, with between *ca* 10-20 % TLP being deteriorated. Broken grains form the bulk of the deteriorated sum at levels of between 4.4 % and 13.8 % TLP. Crumpled and amorphous grains form minor components each at less than 2 %. Corroded grains comprise of type-1 corrosion only, starting at levels of <1 %, but rising to 5 % TLP towards the end of the zone. Indeterminable grains are infrequent at <2 % in the first two levels and <1 % in the rest of the zone and comprise primarily of broken grains.

Percentage LOI is low, starting at *ca* 10 % and rising to *ca* 33 % towards the end of the zone. The samples are all from gyttja with the exception of 436 cm which is from clay.

b) CDDET-B: 421-389 cm; *ca* 9860-9440 BP (*ca* 11,240-10,660 cal BP)

Whilst total deterioration levels are similar to the preceding zone at *ca* 10-20 % TLP, the components change in importance. Type-1 corroded grains increase in representation to between *ca* 5-10 % between 420-402 cm, drop to *ca* 4-6 % at 400 cm and 398 cm, and rise to values in excess of 10 % TLP towards the end of the zone. The level of grains that are broken decreases to between 3-6 % throughout the zone. Type-2 corroded grains occur sporadically at less than 0.5 % TLP, whilst crumpled and amorphous grains continue at similar levels to CDDET-A. Indeterminable grains are rare, never reaching >1 % and comprise a mixture of all indeterminable types.

Percentage LOI is steady at between 50 % and 60 %, with all of the samples originating from gyttja.

c) CDDET-C: 389-309 cm; *ca* 9440-8040 BP (*ca* 10,660-8940 cal BP)

The zone begins with a sharp rise in total deteriorated pollen to in excess of 50 % TLP, peaking at 55 % at 378 cm and dropping fairly steadily from thereon to *ca* 25 % at the end of the zone. This change is due almost entirely to a sharp increase in the level of type-1 corroded grains to >50 % TLP at the start of the zone, dropping to *ca* 20 % at its end. Levels of crumpled, amorphous, broken and type-2 corroded grains are similar to the preceding zone. Indeterminable grains are infrequent at <1 % TLP throughout and comprise primarily of corroded grains.

Percentage LOI rises steadily from 66.7 % to 80 % between 388 cm and 340 cm, then drops to 50 % by 320 cm before recovering to *ca* 70 % towards the end of the zone. All of the samples are from gyttja.

d) CDDET-D: 309-162 cm; *ca* 8040-6430 BP (*ca* 8940-7370 cal BP)

The zone is characterised by low levels of deterioration at between *ca* 10-20 % TLP throughout. Type-1 corroded grains are present at consistently low levels of between 2-12 % and generally around *ca* 6 % TLP. All other deterioration types are present at similar levels to CDDET-C. There is a slight increase in the level of indeterminable grains, although the category rarely exceeds 1 % at any level, with no deterioration form dominant.

Percentage LOI is between 65 % and 100 % throughout and generally around *ca* 70-85 %. The samples come from three sedimentary units, with depths 308-286 cm comprising gyttja, 284-220 cm peat and 216-160 cm peat containing abundant wood fragments.

e) CDDET-E: 162-76 cm; *ca* 6430-5660 BP (*ca* 7370-6450 cal BP)

The zone opens with a rapid rise in total deterioration to >50 % TLP. Pollen preservation is poor with total deterioration between 50-60 % for much of the zone, peaking at 77.5 % at 132 cm. This is primarily caused by a large increase in type-1 corrosion to a maximum of 66.6 % at 132 cm, and in excess of 40 % TLP for the rest of the zone. Crumpled grains increase to their highest representation at *ca* 2-6 % for the bulk of the zone, with type-2 corroded grains also consistently present at between 0.5 % and 2.6 %. Levels of amorphous and broken grains are similar to the preceding zone. The proportion of grains that are indeterminable increases and is consistently in excess of 1 % TLP, with corrosion (undiff.) being the most common cause.

Percentage LOI is high for much of the zone at *ca* 65-85 %, but drops to ~54 % in the last three samples (80-76 cm). Samples between 156 cm and 92 cm come from peat with abundant wood fragments and those above 92 cm are from peat lacking wood fragments.

6.4.1.2 Interpretation

The following section evaluates the main results of the pollen preservation analysis. The discussions centre upon LDPAZs where the preservation data indicate changing taphonomy or that the pollen record may be unreliable or altered in some way. It is not intended to discuss all of the LDPAZs in this section, instead the reader is referred to the summary provided in Table 6.3. Specific points, particularly those relating to individual pollen types, will also be drawn upon in section 6.5 to aid the discussion of the vegetational record.

(i) CDDET-A; *ca* 10,050-9860 BP (*ca* 11,520-11,240 cal BP)

Although the good pollen preservation between *ca* 10,050 and 9860 BP suggests that the pollen record is generally sound, broken grains are at their highest representation. The moderate levels of broken grains coincide with low, but increasing, percentage LOI values (Figure 6.2) and it seems possible that some of the breakage could be the result of mechanical damage during erosional inwash (cf. Birks, 1970). By combining the LOI and pollen preservation data it is plausible to suggest that at least part of the pollen spectra during this period could be composed of reworked (possibly older) palynomorphs derived from the hydrological catchment area. As percentage LOI levels increase to above 40 %, the proportion of grains that are broken drops to a background level of *ca* 5 % for the rest of the core.

(ii) CDDET-C; *ca* 9440-8040 BP (*ca* 10,660-8940 cal BP)

The rapid increase and subsequent gradual decline in type-1 corrosion between *ca* 9440 BP and *ca* 8040 BP (Figure 6.2) is potentially of significance regarding the interpretation of the pollen record. The data indicate that the proportion of pollen grains that had been exposed to prolonged periods of oxygenated conditions increased during this period (see section 4.3.3.1). Only *Betula, Corylus avellana*-type and perhaps Poaceae show elevated type-1 corrosion (Figures 6.3-6.9) and it is subsequently felt unlikely that the high corrosion levels reflect post-depositional drying of the deposit (cf. CDDET-E, see below), as such a process may be expected to affect all pollen types, rather than just these three (although care must be taken with regard to differential susceptibility [Sangster and Dale, 1961, 1964]).

It is possible that the data reflect a period of increased inwashing of pollen from soils or the soil surface either due to elevated surface run-off, or stream activity. An increase in overland sheetwash would require a decrease in evapotranspiration, greater precipitation, or both. Given that the pollen record (Figures 6.11-6.13) suggests an increase in the density of woodland cover and that the major taxa involved are all broad-leaved deciduous species, it seems unlikely that evapotranspiration would have decreased enough to cause the effect. This leaves a change to a wetter climate as the most likely cause of such a process. Unfortunately, detailed records of early Holocene climatic conditions within lowland eastern England are lacking, but Tipping (1996) suggests that the period between *ca* 9000 BP and 8000 BP may have been relatively moist within Britain. This coincides broadly with the dating of CDDET-C.

A final possibility is that the change in the level of type-1 corrosion reflects the activity of a stream flowing into the site. As many of the drainage systems of Holderness are adaptations of natural watercourses (Ellis, 1995) it is possible that the Cess Dale Drain that cuts through the site (Figure 3.8) was present during the early Holocene as a stream. Several studies have demonstrated that the proportion of the pollen loading entering via an inflowing stream can be large (see section 3.2.1). Given that the bulk of the pollen entering a stream will comprise secondarily redeposited, inwashed and eroded pollen (e.g. Hirons, 1988), it is conceivable that a large proportion of the input will have been exposed to prolonged periods of oxygenated conditions and hence, have become corroded. If the grains became temporarily trapped within stream vegetation, or the activity of the stream was seasonal or sporadic, the severity of deterioration may be expected to be high. Variation in stream activity could account for the fluctuations in type-1 corrosion observed during CDDET-C. The possibility that the pollen catchment was distorted in the direction of the stream during this zone, and that some of the pollen may represent an older component, hence, exists. Given the present day topography it is perhaps most likely that the drainage basin for a stream would have been the higher ground to the east of the site. Such a hypothesis would require that the activity of the stream was markedly reduced (or ceased) during zone CDDET-D.

Whilst the cause of the increased corrosion remains uncertain, the percentage LOI curve indicates that it was not associated with significant inorganic erosion. The low levels of crumpled and broken grains also suggest that little mechanical damage occurred during the period. Whatever the cause(s) of the increased type-1 corrosion, the lack of obvious change in the pollen record during the transition from CDDET-C to CDDET-D suggests that the effects of any taphonomical change were minimal in terms of alteration of the pollen record.

(iii) CDDET-E; *ca* 6430-5660 BP (*ca* 7370-6450 cal BP)

The increase in total deterioration across all major pollen types between *ca* 6430 and 5660 BP is particularly obvious. Of interest is the rise in type-1 corrosion and the marked, but smaller, peak in type-2 corrosion, implying that the palynomorphs were exposed to prolonged oxygenated conditions at some time. The observation that all of the major pollen types show this trend suggests that the bulk of the damage was either post-depositional, or occurred during deposition as the result of a process that affected a large proportion of the pollen influx. It is possible that drying of the peat during formation (e.g. due to seasonal fluctuation in the water table) resulted in aeration of the deposit and subsequently corrosion. Alternatively, the data may reflect post-depositional drying of the deposit. It is probable that the sequence was exposed close to the land surface for an undefinable length of time prior to the capping of the site by colluvium. This would have made the upper part of the profile susceptible to drying due to fluctuations in the local water-table, whether climatically-induced or due to evapotranspiration caused by vegetation growing on, or near, the site. Corrosion due to *in-situ* drying of peat deposits has previously been argued by Lowe (1982). The absence of spherules of iron pyrite towards the top of the sequence may support the above hypotheses, but could also reflect the lack of metallic or sulphate ions within the peat matrix (Wiltshire *et al.*, 1994). Drying of the peat may also have caused the break-up of surrounding basin-edge peats, and their subsequent incorporation into the sediment (cf. Tipping, 1987b).

The overall high levels of deterioration for this LDPAZ (generally in excess of 50 % TLP) raise the possibility that the pollen record may have been altered due to the loss of the more susceptible pollen types. Whilst there is an increase in indeterminable grains, the fact that levels rarely exceed 5 % TLP and the high palynological diversity of the zone suggests that any modification of the spectra in terms of the complete loss of pollen types must be slight. The relative representations of the more susceptible types may have decreased though. Levels of Pteropsida (monolete) indet. and *Polypodium* spores reach their highest representation in this zone. Such spores have been noted to be highly resistant to deterioration in soils by Pennington (1965) and whilst they were used by the author to indicate erosion into the site, it is possible that their increased abundances reflect their artificial concentration due to the loss of more susceptible pollen from the sediment. No overall declines in TLP concentrations or accumulation rates are evident during this zone though (Figures 6.18 and 6.19), so the cause of the spore increase remains unclear.

(iv) General points

With the exception of the transition from clay and clayey gyttja to gyttja during CDDET-A (discussed above), no marked changes in pollen preservation occur across stratigraphical boundaries. This suggests that the changes in deterioration levels and forms observed are largely independent of sediment type. In general the indeterminable category is composed predominately of grains damaged by the dominant form of deterioration at the time, although this relationship is not always clear.

6.4.2 Local pollen assemblage zones

The following section describes the local pollen assemblage zones (LPAZs) that have been assigned to the pollen data. Due to the high levels of *Alnus* pollen from 266 cm onwards, *Alnus* is excluded from the pollen sum in the diagrams presented (Figures 6.11-6.16). The bulk of the percentage values given are therefore based upon the modified sum of TLP excluding *Alnus* (TLP*). Any values based upon the sum of TLP including *Alnus* are stated as % TLP. Summary concentration and accumulation rate diagrams are shown in Figures 6.17 and 6.18. Details of the LPAZs are given in Table 6.4.

a) CD-1: 436-391 cm; *Betula*-Poaceae; *ca* 10,050-9470 BP (*ca* 11,520-10,700 cal BP)

Three subzones are suggested for this zone:

i) CD-1(a): 436-421 cm; *ca* 10,050-9850 BP (*ca* 11,520-11,220 cal BP)

Whilst not the base of the core, this subzone covers the basal section in which pollen analysis was undertaken. *Betula* is the dominant component in both percentage and concentration terms, reaching values consistently in excess of 50 % TLP*. *Salix* is the next most important arboreal type at *ca* 5-12 %. *Pinus sylvestris* pollen is present at levels of <5 %, whilst *Juniperus communis* occurs at low frequencies. The herbaceous community is represented primarily by Poaceae undiff. (maximum 46.2 %) and Cyperaceae undiff. (maximum 22.1 %), both of which decline in percentage terms as the subzone progresses. *Filipendula* forms an important component, with *Ranunculus acris*-type present at >2 % TLP*. Occasional grains of Ericaceae occur throughout CD-1(a) and aquatics, particularly *Myriophyllum spicatum* and *Typha latifolia*-type, are well represented. *Equisetum* spores are at their highest recorded level, whilst Pteropsida (monolete) indet. spores are sparse to absent.

Percentage LOI starts at 10 %, but rapidly rises, approaching 40 % towards the top of the subzone. Charcoal and spherule to exotic ratios are both very high. Pollen preservation is good with less than 20 % TLP deteriorated on average, the zone being covered by CDDET-A. Total pollen and spore concentrations start low at *ca* 36,000 grains cm^{-3}, but rise to between *ca* 250,000 and 300,000 grains cm^{-3} above 432 cm.

ii) CD-1(b): 421-403 cm; *ca* 9850-9650 BP (*ca* 11,220-11,120 cal BP)

A series of short-lived palynological changes occur within this subzone. *Betula* and Poaceae undiff. decline, and *Corylus avellana*-type pollen rises to a peak of 40.5 % TLP*. This is accompanied by increases in *Ulmus, Quercus* and *Alnus glutinosa* to maximum values of 4.6 %, 12.3 % and 5.2 % respectively. *Sorbus*-type and *Juniperus communis* are present at low frequencies along with occasional grains of Ericaceae. Herb pollen remains diverse, although *Filipendula* and *Ranunculus acris*-type decline in representation. Aquatic pollen is common with *Nymphaea alba* and *Sparganium emersum*-type consistently in excess of 2 %. *Myriophyllum spicatum* and *Equisetum* decline to <2 %, and Pteropsida (monolete) indet. spores are frequent at up to 10 % TLP*.

Percentage LOI stabilises at between 50 % and 60 %. Spherule to exotic ratios and charcoal levels are reduced, but remain high, and total pollen and spore concentrations vary between *ca* 230,000 and 600,000 grains cm^{-3}. Pollen preservation remains good, with the subzone being covered by CDDET-B.

iii) CD-1(c): 403-391 cm; *ca* 9650-9470 BP (*ca* 11,120-10,700 cal BP)

Corylus avellana-type, *Quercus, Ulmus* and *Alnus* decline to <2 %, although *Corylus avellana*-type recovers again to 9.9 % TLP* at the end of the zone. *Betula, Salix* and Poaceae undiff. increase in representation coincident with the above declines. *Betula* peaks at its highest level of 76.8 % TLP* at 394 cm. *Sorbus*-type and *Juniperus communis* are occasionally present, and *Calluna vulgaris* is the only ericaceous taxon represented during this subzone. The herb, aquatic and spore records are similar to CD-1(b).

Percentage LOI and spherule to exotic levels are similar to CD-1(b), but charcoal levels are slightly higher. Pollen preservation remains good, with *ca* 20 % TLP deteriorated, the subzone being covered by CDDET-B. Total pollen and spore concentrations start at *ca* 160,000 grains cm^{-3} and rise steadily to *ca* 440,000 grains cm^{-3} at the end of the subzone.

b) CD-2: 391-297 cm; *Corylus avellana*-type-*Ulmus; ca* 9470-7840 BP (*ca* 10,700-8670 cal BP)

Two subzones are suggested for this zone:

i) CD-2(a): 391-345 cm; *ca* 9470-8730 BP (*ca* 10,700-9690 cal BP)

The base of the subzone is delimited by a rapid, sustained rise in *Corylus avellana*-type representation to *ca* 60-65 % TLP* and a decrease in *Betula* levels to *ca* 20 %. *Ulmus* expands to levels of 5-9 % and *Pinus sylvestris* continues to be present at <5 %. *Salix* declines to <5 %, *Juniperus communis* is present in one sample only, and *Sambucus nigra* is present in several samples at low levels. Herbs decline in importance although a relatively diverse ground flora is still suggested, with *Achillea*-type, Apiaceae, *Artemisia*-type and *Filipendula* present at <2 %. Aquatics including *Nymphaea alba, Sparganium emersum*-type and *Typha latifolia* are consistently present, whilst

Pteropsida (monolete) indet. spores are present at values of <5 % TLP*. *Equisetum* occurs sporadically at low levels.

Percentage LOI shows a steady increase to in excess of 83 % and spherule to exotic ratios are similar to those found at the end of the preceding zone. Charcoal levels begin relatively high, but decline throughout the zone. Pollen preservation is poorer than in CD-1, DLP consistently being in excess of 40 % TLP and peaking at 55 % TLP at 378 cm. The zone is covered by CDDET-C and part of CDDET-B. Total pollen and spore concentrations are higher than in CD-1 and are generally between 500,000 and 800,000 grains cm^{-3}.

ii) CD-2(b): 345-297 cm; *ca* 8730-7840 BP (*ca* 9690-8670 cal BP)

A sustained rise in *Quercus* marks the start of the subzone, with values reaching a maximum 18.9 % TLP* at 300 cm. *Corylus avellana*-type and *Ulmus* are stable at levels of *ca* 60-70 % and *ca* 8-10 % TLP* respectively. *Pinus sylvestris, Salix* and *Hedera helix* are present at low levels throughout. *Tilia* appears at <2 % towards the top of the subzone. Herb pollen drops to <5 %, with Poaceae undiff. generally <2 % TLP* throughout. The aquatic and spore components are similar to CD-2(a), although *Equisetum* becomes absent.

Percentage LOI values show a sustained drop from *ca* 80 % to *ca* 50 % between 338 cm and 320 cm, before rapidly recovering to levels of *ca* 70-80 % for the rest of the subzone. Charcoal levels are stable and low, and spherule to exotic ratios are similar to CD-2(a), but decrease from 310 cm onwards. Deteriorated pollen levels steadily decrease, but are still quite high through much of the subzone, the subzone being covered by CDDET-C and part of CDDET-D. Total pollen and spore concentrations are initially similar to CD-2(a), but drop to *ca* 400,000 grains cm^{-3} from 322 cm onwards.

c) CD-3: 297-267 cm; *Alnus-Quercus* (*Betula*); *ca* 7840-7060 BP (*ca* 8670-7880 cal BP)

A marked increase in the representation of *Alnus glutinosa* marks the beginning of this subzone, with levels reaching a maximum of 64 % TLP* towards its end. *Quercus* continues to increase to a maximum of 29 %, whilst *Corylus avellana*-type drops to between 40 and 50 % for the bulk of the subzone. *Betula* and *Pinus sylvestris* increase slightly in both percentage and concentration terms, whilst *Ulmus* is stable at *ca* 10% TLP*. *Hedera helix* is consistently present, and *Frangula alnus* occurs at low levels from 282 cm onwards. *Tilia* and *Fraxinus excelsior* are present at low frequencies, and herb levels remain below 3 %. Aquatics decline in significance, becoming absent after 286 cm. *Polypodium* spores are present and Pteropsida (monolete) indet. levels are generally less than 5 % TLP*.

LOI levels are initially between 60 and 65 %, but rise to in excess of 80 % after 278 cm. Charcoal levels are low and similar to the preceding zone and spherule to exotic ratios are very low. Pollen preservation is good with *ca* 10 % TLP deteriorated at the start of the zone, dropping to *ca* 5 % towards the end, the zone being covered by CDDET-D. Total pollen and spore concentrations are fairly constant at between 200,000-400,000 grains cm^{-3}.

d) CD-4: 267-170 cm; *Alnus-Quercus* (*Corylus avellana*-type); *ca* 7060-6500 BP (*ca* 7880-7400 cal BP)

The recovery of *Corylus avellana*-type to in excess of 55 % TLP* marks the opening of CD-4, with the pollen type stabilising at between *ca* 50-60 % for the rest of the zone. *Tilia* percentages fluctuate between <2 % and 5 %, and *Quercus, Ulmus* and *Alnus glutinosa* maintain similar percentage values to CD-3. *Betula* declines to <5 % with *Fraxinus excelsior* again present at low levels. *Pinus sylvestris* declines to levels of <2 % which are maintained throughout the rest of the core. Total herb pollen generally remains low at <3 % TLP* and aquatic taxa are present as occasional grains only.

Polypodium continues at low levels and Pteropsida (monolete) indet. spores are present at up to 8 % TLP*.

Percentage LOI values are consistently in excess of 70 % and charcoal fragments are scarce. Spherule to exotic ratios start and end low, but rise to their highest level since CD-1(c) between 240 cm and 196 cm. Deteriorated pollen is consistently low at <20 % TLP, the zone being covered by CDDET-D. Total pollen and spore concentrations are slightly lower than the previous zone at between 120,000 and 400,000 grains cm^{-3}.

e) CD-5: 170-131 cm; *Quercus-Alnus-Tilia*; *ca* 6500-6160 BP (*ca* 7400-7020 cal BP)

The zone opens with a steady decline in *Corylus avellana*-type from *ca* 50-30 % TLP*, and the expansion of *Tilia* to values approaching *ca* 10 %. The other arboreal taxa remain at similar levels to CD-4, although there is a slight increase in *Quercus* from *ca* 30-40 %. *Hedera helix* is consistent at <2 %. Total herb pollen remains low, but increases slightly to >5 % towards the end of the zone. Pollen from aquatic taxa is absent with the exception of *Sparganium emersum*-type, which is present sporadically. Pteropsida (monolete) indet. spores increase markedly, rising from <5 % to *ca* 30 % TLP* towards the end of the zone.

Percentage LOI values are high throughout at between *ca* 75 and 93 % and spherule to exotic ratios are consistently low. Charcoal levels are similar to CD-4, being low to absent. The level of deteriorated pollen increases markedly as the zone progresses to in excess of 40 % TLP, peaking at 62.5 % TLP at 132 cm, and the zone is covered by CDDET-D and CDDET-E. Total pollen and spore concentrations are similar to those of the previous zone at between *ca* 150,000-300,000 grains cm^{-3}.

f) CD-6: 131-76 cm; *Quercus-Tilia*-Cyperaceae; *ca* 6160-5660 BP (*ca* 7020-6450 cal BP)

This is the topmost zone from the site and shows a number of changes compared to CD-5. *Corylus avellana*-type stabilises at the lower level of *ca* 25-35 % TLP*, and *Ulmus* declines to percentage values fluctuating between 8 % and <2 %. *Tilia* and *Betula* increase slightly in percentage terms, whilst the other arboreal taxa remain at similar values to the preceding zone. There is a marked increase in both the diversity and relative representation of non-woody species, notably Poaceae undiff., Cyperaceae undiff., and Apiaceae. Brassicaceae, Chenopodiaceae, Lactuceae and *Plantago lanceolata* are also consistently present, as are large Poaceae grains. Pteropsida (monolete) indet. spores continue to increase in abundance to levels in excess of 50 % TLP* and *Polypodium* spores are present at levels between *ca* 2-5 % TLP*. There is an increase in the diversity of aquatic species.

Percentage LOI values are fairly stable at *ca* 70-83 %, but drop to a minimum of 53 % after 82 cm. Spherule to exotic ratios are initially similar to CD-5, but spherules become absent after 98 cm. Charcoal levels are consistently higher than in the previous zone, reaching their highest levels since CD-2(a). The peak at 76 cm reflects the transition from peat to soil. Deteriorated pollen levels are high and stable at *ca* 40 % TLP, with the zone being covered by CDDET-E. Total pollen and spore concentrations are initially low at *ca* 39,000-90,000 grains cm^{-3} (the lowest Holocene levels), rising after 120 cm to become similar to those of CD-5.

6.5 Vegetational history

This section is organised according to the approximate cultural periods defined in Appendix 1. This has been done to allow the vegetational record to be viewed in the context of human cultural development within eastern Yorkshire.

(i) The Early Mesolithic; *ca* 10,050-8600 BP (*ca* 11,520-9580 cal BP)

The expansions of *Betula, Filipendula* and other taxa at the start of CD-1(a) are likely to reflect responses to thermal warming at the start of the Holocene. The stratigraphical change from laminated clays to gyttja above 434 cm (*ca* 10,050 BP) suggests the rapid stabilisation of soils and increased autochthonous organic matter production coincident with this vegetational response. A similar sedimentary change has been noted by a number of authors at the Younger Dryas/Holocene transition (e.g. Beckett, 1975; Björck *et al.*, 1996). There is no evidence for a hiatus between the Younger Dryas and Holocene deposits as has been noted elsewhere in the region (Gilbertson, 1984; Walker *et al.*, 1993), so it appears that the site provides a complete record of the earliest Holocene.

The presence of *Betula* pollen to in excess of 60 % TLP* suggests that birch woodland dominated the landscape of the catchment during CD-1(a) (perhaps from *ca* 10,500 BP to *ca* 9850 BP), with the range of pollen from open ground herbs (e.g. *Thalictrum, Rumex acetosella, Artemisia*-type and Lactuceae) suggesting a relatively open canopy. This is supported by the low AP:NAP ratios (Figure 6.14) and the position of the mean subzone score close to the open woodland and damp grassland taxa towards the right of the DCA plot (Figure 6.19). A minimum estimate for the duration of the birch expansion is calculated as *ca* 260 ^{14}C years on the basis of pollen accumulation rates following the method of Bennett (1983a), although this should be taken as tentative given the dating problems mentioned in section 6.3. The *Betula* grain size-frequency distributions presented (Figure 6.20 and also Figure 6.15 for levels analysed) show little evidence for bimodality, with the mean grain sizes indicating that dwarf birch (*B. nana*), if present at all, did not play a significant role in this expansion (based upon the data of Mäkelä, 1996). *Salix* is at its highest representation throughout zone CD-1, possibly fringing the basin as well as forming a mixed *Betula-Salix* scrub. The lack of a discernible time lag between Holocene warming and the expansion of *Betula* and *Salix* is likely to be due to their local presence during the Younger Dryas, as supported by the published data from Holderness (e.g. Bennett 1975, 1981; Walker *et al.*, 1993). The low levels of *Juniperus communis* suggest that the species was not frequent, in contrast to the record from Star Carr (Day, 1995). This may reflect a real difference, although differential loss of the fragile *Juniperus* pollen due to breakage and crumpling may be partly responsible. The status of *Pinus sylvestris* is less certain. Its pollen is generally considered to be over-represented due to the high productivity (Andersen, 1973; Bradshaw, 1981) and ability for long distance dispersal (e.g. Bradshaw and Webb, 1985; Jackson, 1990) of the taxon. A recent study utilising stomatal analysis in conjunction with pollen has shown that pollen levels of <5 % may still indicate local growth though (Fossitt, 1994). Given that *Pinus sylvestris* levels rarely exceed 5 % TLP* throughout the Cess Dell profile it seems most likely that the taxon was either sparse or absent from the pollen catchment. The abundance of *Filipendula* indicates the presence of a tall herb community, and in conjunction with *Ranunculus acris*-type, perhaps reflects areas of damp grassland, whilst the low levels of *Calluna vulgaris, Empetrum nigrum* and *Vaccinium*-type are suggestive of a limited heathland community. The presence of large grass pollen at several levels presumably denotes instances of wild grasses (possibly *Glyceria* or *Elymus*; see section 5.3.2).

Charcoal levels are extremely high during this period (Figure 6.14), but drop at the transition to CD-1(b). Charcoal frequencies seem to be tied closely to the level of erosion, with values falling as the percentage LOI curve increases. This suggests that a large part of the charcoal is reworked, although it seems possible that natural burning may also have occurred within the open birch woodland.

A series of changes occurs in the pollen record during CD-1(b) (perhaps between *ca* 9850 BP and *ca* 9650 BP). The increases and subsequent declines in *Alnus glutinosa, Quercus* and *Ulmus* at such an early date are unusual in pollen diagrams from Britain and require consideration. Whilst the interpolated age range given above is uncertain it is clear that the events occur prior to the sustained *Corylus avellana*-type expansion dated as 9490±70 BP (AA-30870). This places the apparent expansions significantly earlier than generally accepted (Huntley and Birks, 1983).

It is possible that mixing has occurred between early Holocene and relatively more recent deposits, perhaps during coring. This is potentially supported by the date of 9360±70 BP (AA-30877) obtained for the centre of the event which is clearly too young. In order to account for the pollen types present and the apparent uniform composition of the sediment, it would require that the younger sediment originated from the upper part of the gyttja (between 296 cm and 286 cm). Whilst mixing of the outer layers of the profile during coring seems possible, analysis revealed comparable spectra throughout the thickness of the core. It is extremely difficult to envisage how complete mixing between deposits from such different depths could occur either *in-situ* or during coring. In addition, consideration of the rarer pollen types (e.g. *Juniperus communis*) does not indicate a break in the scheme of development, so it seems unlikely that the changes are artificial due to the processes discussed above.

The initial expansion of the *Corylus avellana*-type curve from 424 cm could feasibly reflect local growth, and the date does not seem unreasonable given the location of the site (see Huntley and Birks, 1983). When the ecological tolerance of *Myrica gale* is considered (Stace, 1997), it seems safe to assume that the bulk of the pollen is from *Corylus avellana* and it will be treated as such in the following discussions. The apparent expansions in *Alnus glutinosa, Quercus* and *Ulmus* are somewhat harder to explain as they are considerably earlier than expected. It is possible that the peaks are due to the reworking of older pollen, perhaps as a result of stream action (section 6.4.1.2). The region was subject to considerable glacial activity during the Devensian, leading to intensive scouring of the landsurface and the deposition of considerable thicknesses of till (e.g. Penny *et al.*, 1969; Catt, 1990; Eyles *et al.*, 1994; Ellis, 1995). Because of this activity it is hard to see how previous interglacial deposits (needed to account for such high concentrations of warm temperate pollen types) could have persisted and have been reworked to give the concentrations observed (e.g. *Quercus* reaches almost 35,000 grains cm^{-3}). The pollen preservation data is also unclear. A consistent pattern between the study sites is that the occasional grains of arboreal taxa found prior to their inferred local expansions are often deteriorated, with preservation generally improving upon expansion of the taxa (e.g. Figures 6.5-6.8). This suggests that the occasional occurrences reflect long-distance transport or perhaps reworked grains. This pattern is seen for *Alnus glutinosa*, *Quercus* (and *Corylus avellana*-type), although not clearly for *Ulmus,* during the period of concern (Figures 6.4-6.7). Whether this can be used to suggest long-distance transport followed by limited local growth of these taxa must remain uncertain. It is perhaps unwise to suggest that elm, oak and alder did indeed expand, albeit temporarily, at such an early date within the catchment of Cess Dell given the lack of evidence of a similar pattern from elsewhere in eastern England (but see Bush and Hall, 1987). A final alternative is that the expansions of all four pollen types are the result of a period of marked long-distance transport, although this seems unlikely given the large proportions of the pollen sum involved. The cause(s) of the observed changes, thus, remain unclear.

During CD-1(c) (perhaps between *ca* 9650 and *ca* 9470 BP) a return to a similar vegetational environment to that of CD-1(a) is suggested, as shown by the proximity of the Axis 1 mean subzone scores in the DCA plot (Figure 6.19). *Betula* woodland dominated the catchment and *Salix* was common. There is no evidence that *B. nana* was present (see Figure 6.21). Compared with CD-1(a), the proportion of woodland cover may have increased, or the canopy become more closed, as shown by the higher AP:NAP ratios and overall reductions in herb and heath representation.

The declines in *Alnus glutinosa*, *Quercus*, *Ulmus* and *Corylus avellana*-type from 406 cm (*ca* 9665 BP) could reflect the cessation of reworking, reduced long-distance transport, or local population declines (or at least conditions leading to decreased pollen productivity). Whilst the validity of the data for the more thermophilous taxa is uncertain (see above), the fact that a similar contraction occurs in the *Corylus avellana*-type curves at Sproatley Bog and The Bog at Roos (chapters 8 and 9) suggests that the changes observed reflect real events. There is little in the pollen and charcoal records to suggest that humans played a significant role and it is possible that the decline at Cess Dell is the result of a climatic deterioration. Several periods of climatic revertance have been identified during the early Holocene on both the continental mainland (e.g. Walker *et al.*, 1994; Björck *et al.*, 1996; Björck *et al.*, 1997), and in Britain (e.g. Atkinson *et al.*, 1987; Lowe *et al.*, 1994; Walker *et al.*, 1994; Whittington *et al.*, 1996; Edwards and Whittington, 1997). The timing of the decline at Cess Dell between the interpolated dates of 9640 BP and 9530 BP suggests that this may be a reflection of the Preboreal oscillation (PBO), a cooling event lasting *ca* 150 calendar years that has been identified throughout the North Atlantic region (Björck *et al.*, 1997). The authors dated the event to between 11,300-11,150 cal BP, or between the radiocarbon plateaux at 10,000-9900 BP and 9600-9500 BP, which is in broad agreement with the interpolated dates given above. The role of early Holocene climatic instability in determining the vegetational development of central Holderness will be discussed in more detail in chapter 10.

Corylus avellana-type pollen rapidly rises after 9490±70 BP (AA-30870), dominating the record in both percentage and abundance terms during CD-2. Given the proximity of the date to the 9500-9600 BP radiocarbon plateau, which has a duration of *ca* 350-400 calendar years (Kromer and Becker, 1993; Stuiver and Reimer, 1993), it is possible that the expansion occurred within this plateau. *Betula* declines in percentage representation coincident with this, although concentrations and accumulation rates drop at a slower pace. On the basis of the absolute data it would appear that the transition from a *Betula*- to a *Corylus avellana*-dominated community occurred within *ca* 180 ^{14}C years. A possible mechanism for this shift is the direct replacement of birch by hazel through competition. Whilst it is uncertain whether the ecological tolerances of species have remained unchanged throughout the Holocene, it is an assumption that has to be made if the data are to be interpreted meaningfully (Rackham, 1988). Peterken (1987) suggests that in birch-hazel communities today, birch usually occurs as a high canopy species, with hazel as the understorey. Given that tree birches typically live for 100-200 years (Rackham, 1980), die-back of ageing stands would have left the understorey of hazel as the canopy. Birch may have then declined due to the light-demanding seedlings failing to regenerate beneath this cover. The transition observed could be the result of such replacement averaged over a number of stands. The occasional grains of *Sorbus*-type, *Viburnum* and *Sambucus nigra* indicate the presence of other arboreal taxa within the woodland mosaic. Representation of heathland taxa decreases during the zone, perhaps indicating a net reduction in the area of heathland within the catchment. The overall declining levels of herbs throughout CD-2 suggest that the average proportion of open ground within the catchment decreased as the zone progressed (also shown by AP:NAP ratios; Figure 6.14). Charcoal levels declined rapidly from *ca* 9470 BP, becoming consistently low between *ca* 8730 and *ca* 6160 BP. This is likely to reflect a combination of the reduced flammability of the vegetation (Rackham, 1980), a decrease in the reworked component as erosional inwash lessened, and possibly a trend of decreasing insolation (Mayewski *et al.*, 1996). There is little to suggest that the hazel rise within the catchment was linked to burning by Mesolithic peoples (cf. Smith, 1970; Smith *et al.*, 1989), the expansion seemingly reflecting natural processes (see above and Huntley, 1993).

From 9490±70 BP (AA-30870) increasing accumulation rates suggest the local presence of *Ulmus*, although increased representation in percentage terms does not occur until *ca* 9300±65 BP (AA-30871) when the accumulation rates suggest that the expansion of the genus was almost complete. This expansion occurred within *ca* 410 ^{14}C years. From the absolute data it would appear that *Ulmus* expanded at the expense of *Betula* and possibly *Salix* and Poaceae, supporting the above hypothesis that woodland density increased as zone CD-2 progressed. This is also suggested by the increasing AP:NAP ratios. Elms favour clay-based soils (Huntley and Birks, 1983), and it seems likely that the genus was common on the less waterlogged soils within the catchment.

(ii) The Late Mesolithic; *ca* 8600-5660 BP (*ca* 9580-6450 cal BP)

The next major vegetation change occurred with the expansion of *Quercus* from *ca* 8720±75 BP (AA-30872) in the percentage diagram (i.e. shortly prior to the start of the Late Mesolithic Period). The low *Quercus* influx between *ca* 9360 and 8940 BP may reflect sparse local growth of the genus, but could equally reflect long-distance transport, with the influx data suggesting that major expansion occurred between *ca* 8940 BP and 8450 BP. This gives a minimum expansion time of *ca* 490 ^{14}C years. The expansion of oak appears to have reduced the local populations of *Betula, Ulmus,* and from *ca* 8270 BP *Corylus avellana.* Whilst it is not possible to separate the pollen of *Q. robur* from *Q. petrea* (or indeed their hybrid; Moore *et al.,* 1991), given the ecological tolerances of the two species it is perhaps most likely that *Q. robur* was the more common of the two species on the clayey soils surrounding Cess Dell (Rackham, 1980; Grime *et al.,* 1988; Archibold, 1995).

It is quite possible that the persistence of *Betula* within the record during and after this period is due to its presence as a gap-phase taxon, as previously suggested by Bennett (1986), or it could denote its growth upon ground too damp for other taxa. This compares to earlier periods of the record where its pollen abundance suggests that it may have formed a significant part of the canopy. It is not possible to reconstruct woodland composition from the pollen data, but ecological theory and observations of modern woodland (e.g. Rackham, 1988, 1992) and studies of macrofossils from 'submerged forests' (Clare, 1995) and floodplain deposits (Brown, 1992), indicate that woodland during the Early-Mid Holocene is not likely to have been uniform. Instead it is probable that a mosaic of stands of different mixtures of species existed, with single-species stands in extreme environments or where clonal species were dominant (Rackham, 1992). During CD-2(b) it is likely that *Quercus robur* dominated much of the canopy, with *Corylus avellana* occurring either as an understorey species (Archibold, 1995), or as a distinct canopy component, with canopy height varying according to the precise composition of the mosaic. Depending upon the species involved, *Ulmus* may have occurred in dense groups as a clone, or as scattered individuals (based on the ecological data of Rackham [1980] and Grime *et al.* [1988]). The record also indicates that *Fraxinus excelsior* occurred at low levels, perhaps on the wetter soils and in canopy gaps. Pollen from *Hedera helix* is consistently present throughout the zone at <2 % TLP, with AP:NAP ratios showing that the open ground component continued to decline. From *ca* 8300 BP *Salix* increased in representation, which combined with the regular presence of *Filipendula* from *ca* 8155 BP may indicate increased catchment wetness, or perhaps local growth at the basin edge, possibly as a function of hydroseral succession.

A series of compositional changes occurred within the vegetation of the catchment during CD-3 (after 7830±60 BP [AA-30873]), the most obvious being the expansion of *Alnus glutinosa* to above 60 % TLP*. The pollen data indicate that the taxon was expanding between *ca* 7860 BP and 7500 BP, an expansion duration of *ca* 360 ^{14}C years. Of the other arboreal taxa, only *Ulmus* and the infrequent *Fraxinus excelsior* remain unchanged in representation during the zone. *Quercus* increases in both percentage and concentration terms suggesting that the genus may have undergone a population expansion (or locational shift) within zone CD-3. Although there is no significant increase in the proportional representation of *Tilia,* the influx data suggest that the genus may have expanded locally from *ca* 7830±60 BP (AA-30873), whilst *Betula* increases during the first part of CD-3 before declining. A marked drop in *Corylus avellana* also occurred during the zone.

The cause of this suite of changes is unclear. The fact that the events generally occur prior to the sedimentary transition from gyttja to peat suggests that an altered pollen source area due to the changing depositional environment was not responsible. There is also little in the pollen preservation record to indicate that the pollen spectra may have been altered in any way (see section 6.4.1.2). It may be that the declining species were simply being competitively excluded by the expanding *Alnus glutinosa, Quercus* and possibly *Tilia* populations. Superimposed onto this is the possibility that some (or all) of the taxa were responding to a wider environmental fluctuation. A widespread climatic reversal occurring between *ca* 8400-8000 cal BP and peaking at *ca* 8250 cal BP (*ca* 7500 BP) has been identified in the GISP2 Greenland ice core and many other areas within the northern hemisphere (e.g. Alley *et al.*, 1997; Klitgaard-Kristensen *et al.*, 1998; Barber *et al.*, 1999; Hu *et al.*, 1999). Analysis of the GISP2 ice core suggests that the event was similar in character to the Younger Dryas, being cold (a maximum of 6±2 °C cooler at 8200 cal BP), dry and perhaps windy, but less extreme and comparatively shorter lived (Alley *et al.*, 1997). Increased forest fire frequencies are also suggested (*ibid*). Calibration of the two radiocarbon dates that bound the changes recorded in the Cess Dell pollen spectra suggests that the events occurred between *ca* 8670-8540 cal BP and *ca* 7940-7790 cal BP. This date range corresponds very well with that suggested for the climatic event described above. The incidence of large grass pollen (presumably from wetland grasses; Tables 5.3 and 6.5) and the increases in *Alnus glutinosa* and possibly *Betula* immediately prior to and during the zone are suggestive of increased wetness, at least locally. Whether this is a local expression of the climatic event discussed above (perhaps due to decreased evapotranspiration, or a change in the seasonality of rainfall) will be discussed further in chapter 10.

From 7045±70 BP (AA-30874) *Corylus avellana* percentages recover, although the concentration data suggests that the population was maintained at the lower levels achieved in CD-3. Between 7045±70 BP (AA-30874) and 6500±65 BP (AA-30875) (zone CD-4) a relatively stable woodland composition is indicated with *Quercus* and *Alnus glutinosa* frequent. Given the extremely high levels of alder pollen and the presence of numerous fragments of wood within the deposit above 220 cm, it is likely that a large part of this pollen was produced by trees fringing and growing upon the basin (cf. Huntley and Birks, 1983). Taking the low pollen productivity of *Ulmus* and *Tilia* into account (Andersen, 1973; Bradshaw and Webb, 1985) it is likely that both genera formed a significant component of the woodland mosaic. The low levels of *Betula* are perhaps indicative of a decreased level of disturbance and a denser canopy than in previous zones, although this reduction could be due to filtering of the pollen rain by trees growing on the site. Other rarer arboreal components during this period included *Fraxinus excelsior, Hedera helix, Salix* and *Frangula alnus.*

Between 6500±65 BP (AA-30875) and *ca* 6160 BP (zone CD-5) there is evidence for an apparent change in the composition of the woodland, with *Tilia* and *Quercus* increasing in percentage representation at the expense of *Corylus avellana.* When the absolute data are considered, then although *Corylus avellana*-type influx decreases, the influxes of *Tilia* and *Quercus* remain relatively unchanged, although the overall drop in total accumulation rates hinders interpretation. Given that corrosion and spore levels increase after *ca* 6430 BP, the possibility remains that the decline in *Corylus avellana*-type may represent loss due to its higher susceptibility to deterioration than the other two pollen types (Havinga, 1964, 1984). This is supported by the stratigraphical proximities of the LDPAZ CDDET-E (which is characterised by high levels of corrosion) and the LPAZ CD-5. The similarity is even more marked when the preservation data for *Corylus avellana*-type are considered alone, with the rise in deterioration coinciding almost exactly with the start of CD-5 (Figure 6.4). It may be that the pollen changes observed are, therefore, the result of differential preservation rather than vegetation change *per se.*

During CD-6 (between *ca* 6160 BP and 5660 BP) a number of changes occur within the pollen record. *Corylus avellana* and *Ulmus* decline, and *Tilia* and *Quercus* stabilise at their highest representations. Although *Betula* increases in percentage terms the absolute data suggest that this is largely a proportional effect. There is also evidence for increases in the proportion of open ground (as shown by the lower AP:NAP ratios) and aquatic diversity. Large Poaceae pollen is consistently present (see Figure 6.16) and charcoal fragments reach their highest levels since CD-2(a). The combination of the pollen and pollen preservation data suggests several hypotheses that may account for these changes.

The declines in *Ulmus* and *Corylus avellana*-type may be artefacts of differential pollen preservation, probably due to damage arising during or after deposition (see 6.4.1.2). This is potentially supported by the pollen preservation curves which show corrosion levels to be consistently in excess of 60 % for both *Corylus avellana*-type and *Ulmus* (Figures 6.4 and 6.5). If poor preservation was the sole cause of the declines it would not account for the increases in herbaceous and aquatic diversity, however. This suggests that the palynological changes are not artificial and that the pollen record is reflecting a period of significantly reduced canopy cover.

It is possible that the changes within the pollen record are related to a natural rise in the local water table. There is clear evidence that the aquatic and damp ground components of the pollen rain increased after *ca* 6160 BP (Figures 6.12 and 6.13), with the expansion of a reedswamp/fen community with areas of open water indicated by the presence of *Sparganium emersum*-type, *Potamogeton, Myriophyllum spicatum, M. alterniflorum* and *Equisetum.* Many of the other herbaceous taxa are suggestive of areas of damp grassland, in particular *Ranunculus acris*-type, *Filipendula* and Cyperaceae undiff. The increase in Poaceae undiff. influx probably reflects the contribution of grasses to both the open grassland and reedswamp communities (perhaps as *Phragmites australis*). Although it was not possible to identify all of the Apiaceae pollen to species level, a number of grains were keyed out from each level as belonging to the *Peucedanum palustre*-type of Punt (1984), which includes the damp ground/marsh taxa *Peucedanum palustre* and *Angelica sylvestris.* Many of the other herb pollen types contain species which may be found in marshy or wet meadow communities (including Brassicaceae undiff. and Caryophyllaceae undiff.), whilst those indicative of disturbed, but drier ground (e.g. *Plantago lanceolata, Artemisia*-type and Chenopodiaceae undiff.) may have inhabited the more freely draining areas on ridges or the woodland/damp grassland ecotone.

Several natural processes could have resulted in a rise in the local water table. Although climatic data relating to eastern England are lacking, Tipping (1995) has suggested that increased precipitation occurred in Perthshire at a similar time, and lake levels in south Sweden and Estonia were high at around 6500 BP (Harrison *et al.,* 1993). An alternative possibility is that rising sea levels led to impeded drainage in the catchment, as occurred in the Keyingham and Winestead Valleys (Dinnin and Lillie, 1995b), although Cess Dell lies at a slightly higher elevation so the influence of sea level remains uncertain. As a final consideration, flooding may have been caused by animals such as beavers. If a nearby stream was dammed and a water meadow created, a vegetation pattern similar to that observed may be expected (Coles, 1992). Supporting this is the finding of a beaver log-jam of Neolithic age at Skipsea Withow Gap (McAvoy, 1995), and the suggestion by Dinnin (1995) that a period of woodland clearance in the pollen record from the site dating to the Early Neolithic may be attributable to flooding of the area arising from beaver activity. It seems plausible that grazing may have played a role in maintaining the grassland component over such a long time period (*sensu* Buckland and Edwards, 1984). In order to account for the declines in hazel and elm it would require that the fen and damp-ground communities expanded into areas previously dominated by the taxa.

An alternative possibility is that the vegetational changes result from human clearance activity. Limited clearance of hazel and elm resulting in a reduction in woodland density and the expansion of open ground communities could explain many of the changes visible in the pollen record. Enhanced run-off as a result of this disturbance may have played a role in increasing the local water table and encouraging the expansion of damp ground and wetland communities (cf. Moore, 1975, 1988; Innes and Simmons, 1988). Given the long duration of the period of woodland reduction (*ca* 500 ^{14}C years) it is likely that the pollen record is reflecting the combination of a series of discrete disturbance events.

If the above hypothesis is accepted then the pollen data indicate that sustained clearance activity occurred within the catchment between *ca* 6110 BP and 5660 BP. It also possible that the large Poaceae pollen consistently recorded during CD-6 reflects arable cultivation. Edwards and Hirons (1984) and Edwards (1998) have suggested that the occurrence of cereal-type pollen dating between *ca* 6100 and 5100 BP in a number of pollen diagrams (Table 5.9) could reflect occurrences of early woodland-based cultivation. The ages of the grains at Cess Dell fall within this timespan (Table 6.3). Two points are of relevance concerning interpretation of the record. Firstly, a degree of caution should be applied with regard to the radiocarbon chronology, as the dating of the period of potential cultivation depends largely upon the accuracy of date AA-30876 (6105±65 BP). If this date is artificially old then the bulk of zone CD-6 could easily be Neolithic in age, with the declining elm frequencies perhaps reflecting the 'elm decline' (dated to *ca* 5100-5300 BP in England [Smith and Pilcher, 1973]). Unfortunately this is not testable on the basis of the available data. Secondly, even though the identifications based upon the keys of Andersen (1979) and Küster (1988) and also the combined approach (chapter 5) suggest that at least some of the pollen could originate from domesticated species, the overall results of chapter 5 show that it is not possible to reliably separate the pollen of wild from cultivated taxa using these approaches. Given that wetland and disturbed ground communities are likely to have been common during this period and that grasses from both habitats can produce large pollen (see chapter 5), it is quite possible that the grains originate from wild species. A decrease in canopy density (as observed during CD-6) could also have promoted longer distance transport of pollen from pre-existing grass populations by decreasing the level of filtration (Edwards, 1993). Although conclusions are necessarily tentative, a natural origin for the large Poaceae pollen is perhaps most likely. This is discussed further in section 10.3.2.

The increased charcoal levels during the zone may result from a reduction in woodland density around the basin reducing the number of particles that were filtered, and hence increasing the charcoal influx (Hirons and Edwards, 1990). A second possibility is that the record reflects a real change in the fire regime, whether natural or anthropogenic. It is hard to see how the vegetational communities suggested by the pollen data would burn naturally on a frequent enough basis to produce the consistently increased charcoal levels (Rackham, 1980, 1988), even taking the comments of Tipping (1996) into account. It is possible, therefore, that the signal is the result of anthropogenic burning, most plausibly of camp fires (cf. Bennett *et al.*, 1990). If the case then this supports the hypothesis that the vegetational changes discussed above may result (at least in part) from human activity, although care should be taken as the increase in charcoal fragments is not particularly marked (Figure 6.14).

(iii) Summary

The records indicate the predominately wooded nature of the catchment of Cess Dell between the start of the Holocene and *ca* 5660 BP when sedimentation ceased. A summary of the development of the catchment is presented in Table 6.6. On the basis of the pollen and charcoal data there is little evidence of human activity between the start of the Holocene and *ca* 6160 BP. This suggests that either the vegetation dynamics for this period were controlled by natural ecological and environmental factors, or that any human influence was either palynologically inseparable from that of natural processes, or otherwise invisible in the record. Between *ca* 6160 BP and 5660 BP a plausible argument for sustained anthropogenic activity within the catchment can be produced, although a similar vegetational and charcoal record can be accounted for based upon natural wetland expansion and a changing receipt of charcoal arising from a decline in the vegetation fringing the basin.

Chapter 7: Gilderson Marr: results and discussion

7.1 Introduction

This chapter presents the analytical results of the core obtained from Gilderson Marr. A description of the core is given in section 7.2 and the radiocarbon dating programme is assessed in section 7.3. The results of the pollen analyses are introduced in section 7.4, where deteriorated pollen and local pollen assemblage zones are suggested. Finally, the vegetational and wider development of the catchment of Gilderson Marr is discussed in detail in section 7.5.

7.2 Core description

A detailed description of the core is given in Table 7.1.

The core stratigraphy and palynological results not presented here, suggest that the organic deposits at the base of the core probably date from the Late-Glacial Interstadial, with the overlying laminated clays presumably covering the Younger Dryas. As the core was not bottomed it is likely that the site contains more extensive Late-Glacial deposits than were recovered. The pollen analyses and radiocarbon dating programme suggest that the profile also covers the first six millennia of the Holocene. The core section between 364 cm and 59 cm was sampled for laboratory analyses.

7.3 Radiocarbon dating

Ten AMS radiocarbon dates were obtained for the profile (Appendix 6). The dates seem reasonable with the exception of AA-32306, AA-32307 and AA-32308. These show similar radiocarbon ages despite covering 56 cm of deposit (the dates lie between 240 cm and 183 cm). The dates all come stratigraphically from within the *Phragmites* peat unit, and it is possible that mixing of the deposit by roots has resulted in the lower two of the three dates (AA-32306 and AA-32307) being contaminated by younger material. This would suggest that date AA-32308 provides the most reliable age estimate. Interpolated dates within the LPAZ GM-3 and the first part of GM-4 (sections 7.4.2 and 7.5) should subsequently be treated cautiously.

Interpolation to the base of the gyttja gives a date of *ca* 9800 BP for the lowermost organic deposits. This is somewhat later than the expected date of *ca* 10,000-10,200 BP for the Younger Dryas/Holocene transition, raising the possibility that the earliest Holocene record may be absent from the core. There is little palynological evidence to suggest that this is the case (see 7.5) and it is perhaps more likely that variation in sediment accumulation rates during the time period prohibits accurate interpolation. The interpolated date of *ca* 9800 BP has been retained, but the above discussion was borne in mind when interpreting the data.

A time-depth curve of calibrated and uncalibrated BP dates is presented in Figure 7.1. Sedimentation rates were relatively even within the dated part of the gyttja and within the non-*Phragmites* peat units. The dating problems discussed above mean that sediment accumulation rates within the *Phragmites* peat (between 240 cm and 183 cm) could not be inferred with confidence.

7.4 Pollen data

The following LDPAZs are numbered from the bottom up and prefixed by the initials GMDET, whilst LPAZs are prefixed by the initials GM. LDPAZs are labelled alphabetically and LPAZs numerically.

7.4.1 Deteriorated pollen analysis

7.4.1.1 Local deteriorated pollen assemblage zones (LDPAZs)

A diagram showing total pollen preservation is presented in Figure 7.2, and a series of diagrams showing the preservation characteristics of the major pollen types are given in Figures 7.3-7.8. Total deterioration percentages are based upon the sum of TLP. Full details of the LDPAZs assigned are given in Table 7.2, and a DCA plot of the average LDPAZ and deterioration type scores for the first two axes of the ordination is presented in Figure 7.9.

a) GMDET-A: 364-311 cm; *ca* 9800-9390 BP (11,210-10,600 cal BP)

Pollen preservation is generally good with less than 15 % TLP being deteriorated throughout the zone. Broken grains dominate, but never exceed 10 %. Crumpled and amorphous grains are consistent at levels of less than 2.9 % and 2.3 % respectively, and type-2 corroded grains are sporadically present. Type-1 corroded grains occur at low levels (generally less than 2 % TLP), becoming slightly more frequent above 330 cm. Indeterminable grains are rare, never exceeding 1 %.

Percentage LOI starts low, but rapidly rises from 15 % to *ca* 75 % between 364 cm and 330 cm. Levels then steadily decline to *ca* 60 % towards the end of the zone. The samples come from gyttja with the exception of those below 359 cm, which are from laminated clay.

b) GMDET-B: 311-249 cm; *ca* 9390-8400 BP (10,600-9400 cal BP)

Whilst pollen preservation remains good, total deterioration levels are slightly higher than the preceding zone at between 15-25 % TLP. Type-1 corrosion is the dominant form of damage, fluctuating at values of between 10-18.8 %, peaking at 290 cm and 268 cm. Broken grains drop to stable values of <5 % and crumpled, amorphous and type-2 corroded grains occur at similar levels to GMDET-A. Indeterminable grains remain infrequent with no type dominant.

Percentage LOI steadily declines from the start of the zone to 290 cm (reaching a low of 50 %), before recovering to above 65 % between 288 cm and 270 cm. A second reduction occurs between 268 cm and 264 cm, with values declining to a minimum of 57 %. All of the samples are from gyttja.

c) GMDET-C: 249-211 cm; *ca* 8400-8140 BP (9400-9080 cal BP)

The zone opens with a rise in the level of deteriorated grains. Preservation is particularly poor between 240 cm and 216 cm, with between *ca* 40 % and 60 % of the grains damaged. The bulk of this increase is caused by corrosion, with both forms reaching their highest representation (type-1 corrosion is between *ca* 10% and 30 %, and type-2 corrosion between *ca* 5 % and 24 % TLP for the bulk of the zone). Both forms decline in importance after 216 cm. Crumpled and broken grains also increase to between 3-5 % and 5-11 % TLP respectively, whilst levels of amorphous grains are similar to the preceding zones. Indeterminable grains remain infrequent and are composed primarily of corroded (undiff.) and broken grains.

Percentage LOI is high at between 70 % and 100 % throughout the zone. All of the samples are from *Phragmites* peat.

d) GMDET-D: 211-79 cm; *ca* 8140-4960 BP (9080-5680 cal BP)

Pollen preservation is much improved, with deterioration levels generally below 20 % TLP. This improvement is primarily due to a rapid drop in corrosion at the opening of the zone. Type-1 corrosion becomes stable at <2.5 %, and type-2 corrosion is sporadic for much of the zone, never exceeding 2 %. Broken grains are increase slightly to between *ca* 8-15 % TLP throughout the zone and amorphous grains become more consistent at *ca* 2-5 %. Crumpled grains remain at similar levels to GMDET-C and indeterminable grains are infrequent, with breakage dominant.

Percentage LOI is relatively stable for much of the zone at above 80 %, but declines slightly from 108 cm onwards. Several stratigraphic units are covered by the zone. Samples are from *Phragmites* peat between 210-184 cm, from peat between 182-138 cm and 128-80 cm, and from woody peat between 136 cm and 130 cm.

e) GMDET-E: 79-59 cm; *ca* 4960-4190 BP (5680-4700 cal BP)

Pollen preservation is fair, but slightly poorer than in GMDET-D, with between 20 % and 36.1 % TLP deteriorated. The proportion of grains that are crumpled increases slightly to between 4 % and 9 %, and type-1 corroded grains are present at 2-6 %. Whilst type-2 corroded grains are never abundant, they become consistently present at <1 %. Broken and amorphous grains remain at similar values to GMDET-D, and indeterminable grains are slightly increased at up to 2 % TLP, with no one form dominant.

Percentage LOI is reduced to between 44.4% and 52.9 % TLP throughout GMDET-E. All of the samples are from peat.

7.4.1.2 Interpretation

The following section evaluates the main results of the pollen preservation analysis. The discussions centre upon LDPAZs where the preservation data indicate changing taphonomy or that the pollen record may be unreliable or altered in some way. It is not intended to discuss all of the LDPAZs in this section, instead the reader is referred to the summary provided in Table 7.3. Specific points, particularly those relating to individual pollen types, will also be drawn upon in section 7.5 to aid the discussion of the vegetational record.

(i) GMDET-A; *ca* 9800-9390 BP (11,210-10,600 cal BP)

Whilst the overall low levels of deterioration between *ca* 9800 BP and *ca* 9390 BP suggest that the pollen record is sound within this period, the slight decrease in broken grains as percentage LOI rises may reflect a decline in the inwashed component as the zone progresses (although this relationship is not as clear as at Cess Dell; section 6.4.1.2).

(ii) GMDET-B; *ca* 9390-8400 BP (10,600-9400 cal BP)

Pollen preservation remains good between *ca* 9390 BP and *ca* 8600 BP (GMDET-B), but the increase in type-1 corrosion is of interest. Although the increase coincides with the *Corylus avellana*-type maximum, *Betula* and Poaceae undiff. also show elevated corrosion levels, so it seems unlikely that the change is due solely to the appearance of a susceptible taxon (i.e. hazel cf. Tipping [1987b]). Percentage LOI levels are reduced during this period and the two peaks in type-1 corrosion correspond closely to LOI minima. This suggests that the corrosion may be linked to erosion, perhaps as a result of increased sheetwash from the slopes surrounding the basin. Alternative hypotheses that could explain the corrosion (and LOI) dynamics include limited stream interaction, and post-depositional drying of the basin edge (and subsequent erosion and incorporation of the lake edge deposits). On the basis of the profile it is hard to separate the above possibilities and all three processes would potentially result in the incorporation of non-contemporaneous pollen into the record. Consideration of the pollen profile (Figures 7.10-7.12 and 7.14) suggests that any effects were minimal, but the possibility was borne in mind when discussing the vegetational development of the site catchment.

(iii) GMDET-C; *ca* 8400-8140 BP (9400-9080 cal BP)

The increasing levels of deterioration throughout GMDET-C, are potentially significant. The facts that all of the major pollen types show elevated corrosion (both type-1 and type-2; Figures 7.3-7.8) and TLP concentrations drop, strongly support an argument for damage or loss after the pollen had been deposited within the basin. Seasonal fluctuations in the water-table during sediment formation, or a post-depositional lowering of the water-table may have dried the deposit, hence exposing the palynomorphs to oxygenated conditions. The drop in spherule to exotic ratios shortly prior to the boundary between GMDET-B and GMDET-C may also be linked to drying of the deposit, but could be due to a reduction in the availability of metallic or sulphate ions, as has previously been discussed for zone CDDET-E (6.4.1.2). An alternative hypothesis that the corrosion levels reflect a period of increased inwashing into the basin seems unlikely.

The increases in corrosion and crumpling that mark the start of GMDET-C occur coincident with the stratigraphical change to *Phragmites* peat. It seems likely that this transition signifies the encroachment of a *Phragmites*-dominated community onto a relatively dry basin surface (as supported by the preservation data). The density of roots within the deposit, dating problems previously discussed (section 7.3), and the corrosion data suggest that significant mixing may have occurred within this LDPAZ. The increases in breakage and crumpling during the zone could be partly due to corrosion reducing the mechanical strength of the grains. Levels remain moderate and fairly stable throughout the rest of the core though and would appear to be primarily associated with the process of peat formation.

The pollen preservation data for GMDET-C suggest that the record may have been altered due to damage occurring during or after deposition. Indeed, poor preservation between *ca* 8400 and 8140 BP can be used to explain the bulk of the palynological changes observed in the LPAZ GM-3 (Figure 7.10). The drops in percentage and concentration representation of *Betula, Quercus, Corylus avellana*-type and perhaps *Ulmus* for example (Figures 7.10 and 7.17) coincide with high corrosion (see Figures 7.3-7.6), and it is possible that the declines represent pollen loss rather than changing pollen input *per se.*

(iv) GMDET-E; *ca* 4960-4190 BP (5680-4700 cal BP)

Whilst pollen preservation remains fair during GMDET-E (*ca* 4960-4190 BP), crumpling and corrosion (predominately type-1) levels increase. Percentage LOI decreases significantly within the zone suggesting that considerable erosion occurred from the slopes surrounding the site, and the increase in crumpling may reflect mechanical damage caused during erosional inwash. The increase in corroded grains perhaps signifies the inwash of pollen from the soil or litter layer, which could also account for the elevated levels of Pteropsida (monolete) spores (cf. Pennington, 1965). Corrosion could also have increased as a result of drying of the deposit during or after formation (as argued above for GMDET-C).

The fact that corrosion levels never exceed *ca* 15 % for any of the major taxa (Figures 7.3-7.8) and the high diversity of herb taxa within the zone suggests that deterioration was not extreme enough to have significantly altered the pollen record. It is possible, however, that a low proportion of older pollen may have been introduced to the site. Inwash from the litter layer may also have increased the representation of taxa that are poorly dispersed by air (e.g. *Ilex aquifolium*; Pennington, 1979).

7.4.2 Local pollen assemblage zones (LPAZs)

The following section describes the LPAZs that have been assigned to the pollen data. All percentages are based upon the sum of TLP, with a series of percentage diagrams being presented in Figures 7.10-7.15. Summary concentration and accumulation rate diagrams are given in Figures 7.16 and 7.17, and a DCA plot of the mean taxon and mean LPAZ scores for the first two axes of the ordination is shown in Figure 7.18. Details of the LPAZs are given in Table 7.4.

a) GM-1: 364-317 cm; *ca* 9800-9470 BP (*ca* 11,210-10,410 cal BP)

This zone covers the basal part of the Holocene section of the core. The record is dominated by *Betula*, which accounts for 55-80 % TLP throughout. *Salix* and *Pinus* *sylvestris* are the two next most important arboreal types at *ca* 5-10 % and <5 % TLP respectively. *Juniperus communis* is present at most levels below 334 cm at <3 %, and *Ulmus, Quercus, Alnus glutinosa* and *Tilia* occur in many levels, generally at <2 % TLP. A diverse open ground flora is indicated with Poaceae undiff. (maximum 24.7 %), *Filipendula* (maximum 25 %) and Cyperaceae undiff. (maximum 4.4 %) as the dominant non-woody taxa. Other herbaceous taxa present at <2 % include *Ranunculus acris*-type, *Artemisia*-type, *Thalictrum* and *Rumex acetosella.* Large grass pollen is present in most levels below 348 cm. Occasional grains of *Empetrum nigrum* and *Calluna vulgaris* occur, whilst aquatics, notably *Nymphaea alba,* Potamogetonaceae undiff. and *Sparganium emersum*-type, are well represented. Pteropsida (monolete) indet. spores are present at most levels at *ca* 5-10 % and *Equisetum* occurs occasionally.

Percentage LOI rapidly rises from 15 % at 364 cm to >50 % above 348 cm. Spherule to exotic ratios are high throughout and charcoal levels start very high, but rapidly drop, becoming moderate towards the end of the zone. Pollen preservation is good with <15 % TLP being deteriorated on average (the zone is covered by GMDET-A). Total pollen and spore concentrations vary between *ca* 250,000 and 500,000 grains cm^{-3}, with influx values stable at *ca* 40,000-60,000 grains cm^{-2} yr^{-1}.

b) GM-2: 317-267 cm; *ca* 9470-8850 BP (*ca* 10,410-10,100 cal BP)

Two subzones are suggested for this zone:

i) GM-2(a): 317-297 cm; *ca* 9470-9200 BP (*ca* 10,410-10,330 cal BP)

A rapid rise in *Corylus avellana*-type representation to >70 % TLP marks the opening of this subzone. *Betula* drops steadily from 38 % to 11 % and *Salix* is significantly reduced, being present at <2 % at several levels. The other principal arboreal taxa are present at similar levels to GM-1, although *Juniperus communis* is absent. Ericaceous taxa are only sporadically present. Herbs decline in overall contribution, but remain relatively diverse and Poaceae undiff. continues to be important, but at reduced percentages of *ca* 2-7 % TLP. The aquatic component is similar to the preceding zone, although *Nymphaea alba* declines in importance, and Pteropsida (monolete) indet. is the only spore type consistently present.

Percentage LOI is stable at between 60-70 %. Spherule to exotic ratios and charcoal levels are slightly lower than for GM-1, but remain moderately high, and pollen preservation is good with *ca* 8-17 % TLP deteriorated. The subzone is covered by GMDET-A and part of GMDET-B. Total pollen and spore concentrations increase to between 400,000 and 700,000 grains cm^{-3}, with several levels exceeding 1x10^{6} grains cm^{-3}. Total influx is stable at *ca* 40-60,000 grains cm^{-2} yr^{-1}.

ii) GM-2(b): 297-267 cm; *ca* 9200-8850 BP (*ca* 10,330-10,100 cal BP)

The subzone opens with a sustained rise in *Ulmus,* the genus averaging 6-9 % TLP throughout. *Corylus avellana*-type and *Betula* stabilise at *ca* 70-80 % and *ca* 8-12 % respectively, and *Pinus sylvestris* and *Salix* are present in all samples at <2 %. *Quercus* is present at 2-3 % TLP above 276 cm, and pollen from Ericaceae is absent. The aquatic, herb and spore components are similar to the preceding subzone, although *Nymphaea alba* is absent above 288 cm.

Percentage LOI fluctuates above 60 %, but reaches a low of 50 % at 290 cm, and spherule to exotic ratios are slightly increased. Charcoal levels are initially moderate, but drop after 286 cm to become low. Pollen preservation is slightly poorer (cf. GM-2[a]) with *ca* 12-20 % TLP deteriorated and the subzone is covered by GMDET-B. Total pollen and spore concentrations are high at between *ca* 700,000-1.2x10^{6} grains cm^{-3}, and total pollen and spore influx increases to between 50,000 and 100,000 grains cm^{-2} yr^{-1}.

c) GM-3: 267-207 cm; *ca* 8850-8140 BP (*ca* 10,100-9080 cal BP)

A series of changes occur within the arboreal taxa during this zone. *Quercus* pollen rapidly increases, reaching 15.5 % TLP at 258 cm. *Corylus avellana*-type, *Quercus* and *Betula* steadily decline between 258 cm and 230 cm, before gradually recovering above 228 cm. The taxa decline to minima of 28.9 %, 4.7 % and 2.7 % TLP respectively. *Ulmus* levels are slightly reduced at between 3 % and 4 % throughout the zone, and *Pinus sylvestris* and *Salix* are present at similar levels to GM-2(b). *Hedera helix* and

Rubiaceae undiff. occur at <2 % throughout. Poaceae undiff. pollen increases in importance from 258 cm, peaks at 238 cm (at 59.7 % TLP), and then declines towards the end of the zone (4.2 % at 208 cm). Ericaceae pollen remains absent and pollen from aquatics becomes sparse above 240 cm. *Sphagnum* is present at levels of <3 %, and Pteropsida (monolete) indet. spores increase in representation, peaking at 26 % TLP at 244 cm.

Percentage LOI is high throughout at *ca* 70-100 % and both spherule and charcoal levels are very low. Pollen preservation becomes poor after 250 cm and the zone is covered by GMDET-C and parts of GMDET-B and GMDET-D. Total pollen and spore concentrations steadily decline, stabilising at *ca* 200-400,000 grains cm^{-3} above 256 cm. Calculation of total pollen and spore influx is hindered by the dating problems of the zone (section 7.3), but levels are low during the earlier part of the zone at *ca* 20,000-40,000 grains cm^{-2} yr^{-1}.

d) GM-4: 207-137 cm; *ca* 8140-7200 BP (*ca* 9080-8000 cal BP)

The zone opens with the complete recovery of the major arboreal taxa. *Corylus avellana*-type dominates the record in absolute and percentage terms, accounting for 65-70 % TLP until 158 cm, after which its representation drops to *ca* 45-50 %. *Quercus* and *Ulmus* are stable at levels of *ca* 8-14 % and *ca* 3-5 % respectively. *Betula* is initially present at *ca* 7-10 %, increasing to 12-25 % above 158 cm, and *Tilia* and *Fraxinus excelsior* occur at <2 % TLP. *Alnus glutinosa* is present at *ca* 3 % from 158 cm onwards. Pollen from Ericaceous taxa is common throughout the zone particularly *Calluna vulgaris* (maximum 7.7 %) and *Empetrum nigrum* (maximum 10.4 %). Total herb pollen is low, with Poaceae never exceeding 2 %, and aquatic pollen only occurs sporadically. Spores are relatively well represented, with *Polypodium* and *Pteridium aquilinum* present in most samples.

Percentage LOI is high at >80 % throughout the zone and spherules are scarce, being absent from several samples. Charcoal levels are initially very low, but increase above 180 cm to fluctuate between moderate and high. Pollen preservation is improved with *ca* 15-25 % TLP deteriorated, the zone being covered primarily by GMDET-D (the lowest two samples are within GMDET-C). Total pollen and spore concentrations increase to between *ca* 400,000 and 600,000 grains cm^{-3} and total pollen and spore influx starts at *ca* 50,000-100,000 grains cm^{-2} yr^{-1}, before dropping to *ca* 15,000-40,000 grains cm^{-2} yr^{-1} above 184 cm.

e) GM-5: 137-91 cm; *ca* 7200-5430 BP (*ca* 8000-6240 cal BP)

A number of changes mark the opening of the zone. *Corylus avellana*-type and *Ulmus* drop in representation to 13.7 % and <2 % TLP respectively before recovering to their original representations towards the end of the zone. *Alnus glutinosa* expands rapidly at the start of the zone and stabilises at *ca* 10-20 % TLP, whilst *Betula* representation fluctuates between 25 % and 45 %. *Quercus* starts and ends the zone at *ca* 20 % TLP, but declines in importance between 116 cm and 100 cm. *Pinus sylvestris* and *Salix* are present at similar levels to the preceding zone, and *Tilia, Frangula alnus* and *Fraxinus excelsior* are present at <5 % below 112 cm. *Calluna vulgaris* and *Vaccinium*-type levels continue as for GM-4, but *Empetrum nigrum* is much reduced in representation. Large grass pollen is consistently present between 128 cm and 136 cm and *Plantago lanceolata* and *Ranunculus acris*-type are present at low levels below 108 cm. The spore and aquatic pollen records are similar to the preceding zone, although *Sparganium emersum*-type is consistently present at low levels below 118 cm.

Percentage LOI remains high at 70-100 % and spherule to exotic ratios are slightly increased (cf. GM-4). Pollen preservation is similar to GM-4, the zone also being covered by GMDET-D. Charcoal levels start and end high, but are low between 124 cm and 104 cm. Total pollen and spore concentrations are high, frequently between 900,000 and 1.9x10^{6} grains cm^{-3}, although total pollen and spore influx is similar to the latter part of GM-4.

f) GM-6: 91-59 cm; *ca* 5430-4190 BP (*ca* 6240-4700 cal BP)

This is the topmost zone from the site and shows a suite of changes. *Ulmus* declines to <2 % for the bulk of the zone and *Corylus avellana*-type drops initially to 10 % TLP, but recovers to *ca* 20 % above 76 cm. *Betula* and *Quercus* both expand to *ca* 30-45 %

and 20-40 % respectively. *Tilia* increases to *ca* 3-5 % for much of the zone, and *Alnus glutinosa, Pinus sylvestris* and *Salix* continue at similar levels to GM-5. *Fraxinus excelsior, Frangula alnus, Ilex aquifolium* and *Sorbus*-type are present at most levels at <2 % with Ericaceaous taxa present at low levels only. Both the diversity and relative representation of herbaceous taxa increase markedly, with the range of open ground species including *Plantago lanceolata, Ranunculus acris*-type, Lactuceae undiff. and Chenopodiaceae undiff. Poaceae undiff. is consistently present at *ca* 3-8 % TLP with large Poaceae grains being present in most samples. The spore record is similar to GM-5 with the exception of Pteropsida (monolete) indet. which increases to *ca* 3-11 % TLP, and there is an increase in aquatic diversity.

Percentage LOI drops steadily to 62.5 % at 80 cm and stabilises at *ca* 45-50 % above this depth. Spherule to exotic ratios are similar to the preceding zone and charcoal levels are moderate to high and relatively stable. Deterioration levels increase, but preservation remains good at *ca* 20-30 % and the zone is covered by GMDET-E and part of GMDET-D. Total pollen and spore concentrations are extremely high, consistently being in excess of $1.0\text{x}10^6$ grains cm^{-3} and peaking at $2.3\text{x}10^6$ grains cm^{-3} at 70 cm. Total pollen and spore influx remains similar to the preceding zone at *ca* 15,000-40,000 grains $\text{cm}^{-2}\ \text{yr}^{-1}$.

7.5 Vegetational history

In keeping with chapter 6, this section is organised according to the approximate cultural periods defined in Appendix 1. This has been done to allow the vegetational record to be viewed in the context of human cultural development within eastern Yorkshire.

(i) The Early Mesolithic; *ca* 9800-8600 BP (*ca* 11,210-9580 cal BP)

The stratigraphical change from clay to gyttja seems to mark the onset of Holocene deposition, with the rise in the percentage LOI curve (Figure 7.13) suggesting that the landscape of the catchment rapidly stabilised (and lake productivity increased) after this transition. Whilst the interpolated date for the earliest organic deposit of *ca* 9800 BP raises the possibility that part of the early Holocene may be missing from the record (section 7.3), any depositional hiatus must have been short-lived on the basis of the palynological data, which is very similar in character to the earliest Holocene records from the other study sites (see below and chapter 10).

Prior to *ca* 9645±80 BP (AA-32302) the record is dominated in both percentage and absolute terms by *Betula*, with the size-frequency distribution (Figure 7.19) indicating that *B. nana* did not contribute significantly to the pollen rain (based upon the data of Mäkelä, 1996). Although the percentage data show no obvious *Betula* expansion during GM-1 (Figures 7.10 and 7.14), the concentration diagram (Figure 7.16) suggests that the genus may have been expanding between the depths of 360 cm and 352 cm. Unfortunately, the poor dating controls mean that no satisfactory estimate for the duration of this expansion can be made. It seems likely that birch woodland dominated the catchment during the above period, with the relatively high levels of *Salix* suggesting that the genus formed a significant canopy component. Even taking into account the reservations concerning differential pollen preservation discussed in section 6.5 it is unlikely that *Juniperus communis* was frequent, and it seems probable that *Pinus sylvestris* was scarce or absent from the catchment (see section 6.5 and also Willis *et al.,* 1998 for discussion). The wide diversity of open ground herbaceous taxa (e.g. *Artemisia*-type, *Thalictrum, Rumex acetosa* and *R. acetosella*), and the presence of Poaceae undiff. at up to 24.7 % TLP indicates that the woodland canopy was relatively open. This is supported by the very low AP:NAP ratios of between 2:1 and 10:1, and the position of the mean subzone score amongst the characteristically more open ground taxa towards the right-hand side of the DCA plot (Figure 7.18). It is likely that areas of damp grassland existed within the catchment given the presence of *Filipendula* (at up to 25 % TLP), *Ranunculus acris*-type and possibly Cyperaceae undiff., although much of the latter pollen type may have originated from the basin-edge community. Large grass pollen is also consistently present and presumably originates from wild taxa (perhaps *Glyceria* or *Elymus*; see sections 5.3.1.1 and 5.3.2). As at Cess Dell the low levels of *Calluna vulgaris* and *Empetrum nigrum* indicate the presence of a limited heathland community. Throughout GM-1 the basin supported a rich aquatic flora, with *Nymphaea alba* particularly frequent.

Charcoal influx is initially very high, but rapidly decreases as GM-1 progresses. As at the other study sites, the decline in influx coincides with increasing percentage LOI values, suggesting that a large proportion of the charcoal input during the earliest Holocene was the result of erosional inwash.

After *ca* 9645±80 BP (AA-32302) a series of vegetational changes occurred within the pollen catchment, the most obvious being the increase in representation of *Corylus avellana*-type pollen. As previously discussed in section 6.5 it is likely that the bulk of this pollen originated from *Corylus avellana* rather than *Myrica gale*, and it will be treated as such in the following discussions. The absolute data suggest that *Corylus avellana* was locally present at relatively low levels between *ca* 9645±80 BP (AA-32302) and *ca* 9500 BP, with major expansion only occurring after *ca* 9480±115 BP (AA-32303). Although the absolute data suggest that the initial *Corylus avellana* expansion had little effect on *Betula* representation, the major expansion appears to have been at the expense of the genus, the replacement of a *Betula*- by a *Corylus avellana*-dominated community occurring within *ca* 260 ^{14}C years (calculated following Bennett, 1983a). It is likely that this transition was the direct result of competitive exclusion (see section 6.5 for full discussion).

Two points are worthy of note concerning the expansion of *Corylus avellana* at Gilderson Marr. Firstly, on the basis of the radiocarbon dates it is quite possible that the initial local expansion occurred within the 9600-9500 BP radiocarbon plateau (Kromer and Becker, 1993; Stuiver and Reimer, 1993), as previously argued at Cess Dell (section 6.5). This makes estimating the calendar date of the expansion problematic. Secondly, there is no evidence that the early part of the rise was interrupted as seen at the other three study sites. This is interesting given that the expansion of the taxon appears to have occurred at a similar date at all sites (but see above), and that a regional climatic revertance event has been proposed to account for the contractions in the hazel curves at Cess Dell, The Bog at Roos and Sproatley Bog. The possibility that the apparent lack of response at Gilderson Marr reflects local variation in response to a regional climatic signal is discussed in detail in section 10.2.4.

Several other vegetational changes occur coincident with the local expansion of *Corylus avellana* (i.e. between *ca* 9640 and 9220 BP). *Juniperus communis* and *Empetrum nigrum* disappear from the record and herb diversity decreases slightly. In particular Poaceae undiff., *Filipendula* and *Thalictrum* are significantly reduced in both percentage and absolute terms. This suggests that the canopy became more closed (or that the proportion of ground occupied by woodland increased) with time during GM-1 and GM-2(a), a hypothesis supported by the steadily increasing AP:NAP ratios (Figure 7.13). The low levels of *Sorbus*-type and *Viburnum* (presumably *V. opulus*; Stace, 1997) indicate that the taxa were also present and ferns formed an important part of the ground flora (as shown by the moderate levels of Pteropsida [monolete] indet. spores; Figures 7.12 and 7.14).

Whilst *Ulmus* does not increase in percentage terms until *ca* 9210±85 BP (AA-32304), accumulation rates suggest that the genus may have been expanding locally from *ca* 9500 BP, with the duration of the expansion calculated as *ca* 400 ^{14}C years. The expansion of *Ulmus* seems to have reduced the local populations of *Betula* and possibly *Salix*, although as the expansion overlaps that of *Corylus avellana,* any conclusions concerning competitive displacement must remain tentative. *Ulmus* was probably present on the more freely draining soils of the slopes surrounding the basin during GM-2(a), but only became common during GM-2(b). The trend of decreasing herb diversity (discussed above for GM-1 and GM-2[a]) continues with taxa such as Chenopodiaceae undiff., *Achillea*-type and *Solidago virgaurea*-type becoming less frequent, and it is likely that a mixed *Ulmus-Corylus avellana* woodland dominated much of the site catchment from *ca* 9210±85 BP (AA-32304) until *ca* 8865±110 BP (AA-32305). The increasing woodland density during GM-2(a) and GM-2(b) shows clearly in the DCA plot (Figure 7.18), with the mean subzone scores located amongst the woodland taxa on the left-hand side of the plot. The variation evident in the AP:NAP ratios (Figure 7.13) is almost entirely due to small fluctuations in the representation of Poaceae undiff.

Charcoal levels decline with the expansions of *Corylus avellana* and *Ulmus*. This is likely to be a reflection of decreasing erosional input, reduced flammability of the vegetation (cf. Rackham, 1980, 1988), and greater filtration of fragments by the increasing canopy density (cf. Hirons and Edwards, 1990). The slight increase in charcoal to pollen ratios towards the end of GM-2(b) and early in GM-3 (*ca* 9270-9120 BP) may be related to an increase in the reworked component, as percentage LOI declines during this period. There is little to suggest any significant vegetational disturbance coincident with this trend, although minor disturbances of small aggregate spatial extent may have occurred (see chapter 3).

From *ca* 9150 BP the absolute data indicate that *Quercus* may have begun to colonise locally, with the accumulation rates (Figure 7.17) suggesting that the genus expanded slowly until *ca* 8870 BP, when a more marked expansion occurred until *ca* 8625 BP. It is this latter phase of expansion that is most evident in the percentage diagram (Figure 7.10). Assuming that the initial slow increase in representation reflects local growth rather than long-distance transport, the total expansion took *ca* 525 ^{14}C years. As previously discussed in section 6.5 it is probable that *Q. robur* provided the bulk of the pollen influx, with the taxon likely to have been common on the clay soils of the slopes surrounding the site. Total pollen concentrations and accumulation rates drop at the GM-2(b)/GM-3 boundary making it hard to assess which taxa were reduced as a result of the *Quercus* expansion, but it is possible that *Betula, Ulmus* and *Corylus avellana* declined due to competitive exclusion. From *ca* 8870 BP *Hedera helix* became a consistent component of the woodland mosaic. Charcoal influx becomes particularly low coincident with the hypothesised local expansion of *Quercus* (*ca* 9150 BP), with fragments scarce until *ca* 8015 BP. It is probable that this reduction was the result of similar processes to those discussed above.

(ii) The Late Mesolithic; *ca* 8600-5500 BP (*ca* 9580-6310 cal BP)

After the expansion of *Quercus,* herb diversity declines and AP:NAP ratios increase slightly to *ca* 30-60:1, suggesting a decrease in canopy openness and relatively complete woodland cover within the pollen catchment. Between 254 cm and 208 cm (*ca* 8525 BP and 8140 BP), however, AP:NAP ratios drop to values of between 6:1 and 20:1. This is largely due to percentage declines in *Betula, Quercus, Corylus avellana* and *Ulmus,* and a marked increase in Poaceae undiff. (Figure 7.14). Similar trends are seen in the concentration data, but the dating problems associated with this part of the core (see section 7.3) mean that the accumulation data is unreliable, so shall not be considered further. Besides the increase in Poaceae undiff., there is little to suggest that the woodland mosaic became disturbed and the canopy more open during GM-3, with Rubiaceae undiff. the only other potentially dryland pollen type increasing in representation. It is perhaps more likely that the declines in the arboreal taxa reflect pollen loss due to corrosion, rather than woodland disturbance, as discussed in section 7.4.1.2. The increasing influx of Poaceae undiff. pollen can be explained by consideration of the core stratigraphy. All of the samples from between 248 cm and 208 cm are from within *Phragmites* peat, and as *Phragmites* has a mean pollen size of <37 µm (Andersen, 1979; Hall, 1991; but see Küster, 1988), its pollen would have been included in the Poaceae undiff. category of this study. The high levels of Poaceae undiff. pollen are, therefore, probably the result of local production by *Phragmites* stands growing on the peat surface.

When the above discussion is considered, there is no reason to suggest that the woodland mosaic was significantly disturbed during GM-3 (between *ca* 8850 BP and *ca* 8140 BP), with a mixed *Quercus-Ulmus-Corylus avellana* canopy dominant. *Betula* formed a lesser component, perhaps as a gap-phase taxon (cf. section 6.5 and Bennett, 1986).

During GM-4 there is evidence for the expansion of a heathland community within the pollen catchment, with total heath representation at *ca* 5-10 % TLP for much of the zone (Figures 7.11 and 7.15). *Empetrum nigrum* dominates the input prior to *ca* 7825 BP and *Calluna vulgaris* between *ca* 7790 BP and 7230 BP, but the occurrence of *Vaccinium*-type pollen in most samples indicates that the community was relatively diverse. The consistent presence of *Pteridium aquilinum* spores throughout GM-4 may be due to the presence of the taxon within the heath vegetation, but it could equally reflect its growth within the woodland understorey (Grime *et al.*, 1988; Fitter *et al.*, 1995). The abundance of *E. nigrum* is interesting as the species is now restricted in northern England to upland sites with cool, moist climates (Grime *et al.*, 1995).

Given that the Ericaceous species mentioned above are low-lying and entomophilous, they may be expected to be relatively under-represented in the pollen record and as such the values observed could indicate a considerable area of heathland within the site catchment. There is no evidence within the pollen data to suggest that the heath taxa expanded at the expense of any of the woodland species. Instead it appears that expansion was into areas previously occupied by palynologically silent taxa or grasses (i.e. Poaceae undiff.; see Figures 7.10-7.12, 7.16 and 7.17). It is possible that this expansion occurred on the slopes surrounding the site (Figure 3.12), but expansion onto the basin surface itself is suggested by the presence of *Vaccinium* sp. roots (Paul Buckland, pers. comm.) within the core between *ca* 200 cm and 180 cm (*ca* 8110 BP and 7990 BP). Whether the heathland expansion reflects growth entirely upon the basin surface (which would explain the lack of reduction in dryland taxa), or includes some growth around the site is uncertain.

Charcoal influx increases markedly after *ca* 8020 BP (Figure 7.13) and remains high throughout much of GM-4. Whilst the fire record is notoriously difficult to interpret in terms of cause and effect (e.g. Patterson *et al.*, 1987; Bennett *et al.*, 1990; Tipping, 1996), a number of conclusions can be made. Firstly, the high charcoal to pollen ratios indicate that burning occurred within the site catchment, as it is hard to see how such values could reflect an increase in the long-distance component. Secondly, increased charcoal levels only occur after the initial expansions of *C. vulgaris* and *E. nigrum*. This suggests that a changing fire regime was not the proximal cause of the heathland expansion. *Melampyrum*, a genus often associated with the colonisation of burnt land (e.g. Moore *et al.*, 1986; Innes and Simmons, 1988; Simmons and Innes, 1996b, 1996c), is present at low levels throughout the zone, and it is possible that the increased charcoal influx reflects burning of the heath community. There is no evidence in the pollen record to suggest that other vegetation types were affected (Figures 7.10-7.12). The charcoal peak at *ca* 7785±105 BP (AA-32311) is of sufficient magnitude to raise the possibility that some burning may have occurred within vegetation growing upon the basin surface.

The cause of this hypothesised burning is purely conjectural, but it is possible that it reflects natural combustion of a susceptible vegetation type in a climate inducive for burning (cf. Tipping, 1996). A similar hypothesis has been proposed to account for the general increase in charcoal levels in a number of sites across Scotland at a similar time period (*ibid*). It is questionable whether natural ignition (presumably by lightning strikes) would have occurred on a frequent enough basis within the heath vegetation to account for the charcoal record though. An alternative (and perhaps more likely) hypothesis is that the increase in charcoal fragments reflects anthropogenic burning, perhaps of the heathland and possibly supplemented by input from campfires. This would imply a human presence close to the basin, at least intermittently, between the periods of *ca* 8020 and 7530 BP. The lack of palynological evidence for disturbance around the site, and the absence of a corroboratory archaeological record (Figure 3.12), mean that such a hypothesis should be treated cautiously, particularly given the existence of a naturally flammable vegetation type during the time period of concern. The possibility that humans may have burned the heath community, whether accidentally or intentionally (cf. Mellars, 1976; Simmons and Innes, 1996b) remains, however. The usefulness of the charcoal record in detecting human activity within Holderness is discussed further in section 10.3.2.

As previously suggested, the pollen evidence indicates that the woodland mosaic was relatively stable during much of GM-4 (i.e. between *ca* 8140 BP and 7570 BP), with the addition of *Fraxinus excelsior* as an infrequent canopy component the only noticeable change (Figure 7.10). Between *ca* 7570 BP and 7230 BP, there is evidence for a compositional change with *Corylus avellana* pollen influx declining. The cause of this change is uncertain as it does not seem to be associated with the significant expansion of any other taxa and the AP:NAP ratios do not indicate an increase in the proportion of open ground (see Figure 7.13). *Tilia* and *Alnus glutinosa* do not expand locally until after the decline and whilst *Betula* increases in percentage abundance, the absolute data suggests that this is primarily a proportional effect due to the decrease in hazel influx. It is possible that the decline in hazel pollen production is a response to a climatic fluctuation, with the start date for the decline broadly coinciding with the proposed cooling trend centred upon *ca* 7500 BP (Alley *et al.*, 1997; Barber *et al.*, 1999; Hu *et al.*, 1999) and discussed in detail in section 6.5. This possibility is discussed in more detail in section 10.2.4.

A number of changes occur within the arboreal and herbaceous floras during the first half of GM-5 (*ca* 7200-6005 BP). Accumulation rates suggest that *Tilia* began to expand locally from *ca* 7380 BP, but only became common after *ca* 7160 BP, with the duration of the expansion calculated as *ca* 295 ^{14}C years. *Alnus glutinosa* became locally frequent at a similar time, with rapid expansion occurring between *ca* 7270 BP and 7010 BP, a duration of *ca* 260 ^{14}C years. The low influx levels between *ca* 7490 BP and 7300 BP could reflect sparse local growth of the taxon, but it is equally likely that they represent long-distance transport, as perhaps suggested by the poor preservation of the pollen during much of this period (see Figure 7.7). Assuming the validity of the radiocarbon dates, this places the local expansion of *Alnus glutinosa* significantly later than at the sites of Cess Dell and The Bog at Roos (see chapters 6 and 9), but this is perhaps unsurprising given the marked variability observed for the event across the British Isles (Chambers and Elliott, 1989; Bennett and Birks, 1990). Gilderson Marr lies at a slightly higher elevation than the other two sites and is surrounded by a rim of comparatively high ground (see Figures 3.5, 3.8 and 3.12). It is possible that the taxon was able to migrate rapidly into the low-lying valleys close to Cess Dell and The Bog at Roos, but that progress was slower across the higher (presumably drier) ground close to Gilderson Marr, perhaps due to a lower competitive ability at the seedling stage of growth.

The representations of a wide range of other taxa also change at the start of GM-5. Whilst the percentage decline (and subsequent recovery) in *Corylus avellana* pollen is partially a proportional effect due to the increasing *Betula* input, the absolute data suggest that the taxon may have become less frequent. *Ulmus* also declines in absolute terms at the start of the zone. There is no evidence for a depositional hiatus at the GM-4/GM-5 boundary and on age grounds, it is unlikely that the drop in elm represents the classical 'elm decline' (*sensu* Scaife, 1988) which may occur at the start of GM-6. It is also unlikely that the decline is the result of competitive exclusion by the expanding *Betula, Alnus glutinosa* or *Tilia* populations, as the genus recovers before the influx from any of the above taxa declines. Competitive exclusion may account for the possible drop in *Corylus avellana* representation though.

Increased disturbance during the first half of the zone is suggested by the occurrence of herb taxa such as *Plantago lanceolata, Achillea*-type and *Artemisia*-type, with the increased frequencies of *Betula, Fraxinus excelsior* and *Sorbus*-type providing further evidence for a relatively more open canopy (cf. Innes and Simmons, 1988). It is possible that the low levels of *Rhinanthus* and *Ranunculus acris*-type indicate an increase in the proportion of grassland, although there is no obvious change in Poaceae undiff. representation. The latter observation is interesting, but does not necessarily conflict with the hypothesis of increased disturbance, with Simmons and Innes (1996a) reporting that Poaceae representation rose in only 22 % of 58 mid-Holocene disturbance phases investigated from sites in Britain (albeit in upland locations).

The consistent presence of *Frangula alnus* and *Sparganium emersum*-type prior to *ca* 6240 BP and possibly the increase in *Betula* influx (but see above), indicates the expansion of damp woodland or carr coincident with the above changes. Spherule to exotic ratios also increase suggesting increased wetness within the deposit (Figure 7.13). This may be due to increased runoff as a result of the inferred disturbance event discussed above (cf. Moore, 1975, 1988; Innes and Simmons, 1988), although other possibilities such as a climatically- or otherwise induced shift in the local water table, could also apply.

The data thus suggest both prolonged disturbance in the dryland vegetation, possibly associated with declining elm (and perhaps hazel) representation, and an expansion of the moist-ground flora. The lack of a discernible disturbance signal within the AP:NAP ratios (Figure 7.13) can largely be explained by the percentage decline in *Calluna vulgaris*. The taxon is included along with herbs and grasses within the category of NAP. The reduction in *Calluna* frequencies subsequently offsets the increased input from herbaceous taxa.

Charcoal levels are moderate to high at the start and end of GM-5, but low between *ca* 6780 BP and 5930 BP. These trends mirror the pollen influx curve for *Calluna vulgaris* (Figure 7.17), suggesting that the incidence of fire during the zone may be closely linked to the presence of a combustible vegetation type, as previously argued for GM-4. Unlike zone GM-4, though there is also evidence for the wider alteration of the woodland mosaic, and whilst much of this may be related to a hydrological or ecological change (e.g. a raised water-table and the expansions of *Alnus glutinosa* and *Tilia*), increased human disturbance cannot be ruled out on the basis of the available data.

Low magnification scanning of all samples within the zone for large grass pollen consistently located grains between *ca* 7160 BP and 6850 BP, but found that they were absent from the upper part of the zone (with the exception of an isolated occurrence; see Figure 7.15 and Table 7.5). Whilst some of the grains were inseparable from the cultivated genera of *Avena* and *Triticum* using the techniques employed in this study (Table 5.4 and chapter 5), it seems unlikely that they signify the onset of arable cultivation within the catchment given their early dates (cf. Edwards and Hirons, 1984; Edwards, 1998), and they are more likely to originate from wild (possibly wetland) grasses. This is interesting when viewed in conjunction with the rest of the data, which suggest that high charcoal production and increased disturbance of the woodland canopy characterised the period. Had these events occurred at an immediately pre-Neolithic or Neolithic date it would be tempting to suggest that limited arable cultivation occurred in the catchment during the period, a conclusion which is of obvious concern. The usefulness of utilising large grass pollen to detect arable agriculture within eastern Yorkshire is discussed in detail in chapter 10.

The pollen record suggests that between *ca* 6240 and 6005 BP the catchment vegetation gradually returned to a composition similar to that occurring late in GM-4, and was then relatively stable until *ca* 5460 BP. *Alnus glutinosa* formed the only significant addition and was probably locally common around the site, perhaps on the lower-lying land running parallel to the basin (Figure 3.12). After establishment, pollen influx for the taxon remains fairly constant suggesting that the population was largely unaffected by the changes that occurred during GM-6 (see below).

(iii) The Neolithic; *ca* 5500-4190 BP (*ca* 6310-4700 cal BP)

The opening of the Neolithic Period approximately coincides with the start of zone GM-6, which is dated to *ca* 5430 BP. A number of marked changes occur in the pollen, charcoal and erosional records during this LPAZ. *Ulmus* declines to <2 % TLP soon after 5445±75 BP (AA-32310; Figure 7.15), although the decline in influx is less marked (Figure 7.17). The timing of this event is early when compared to much of the British Isles (e.g. Smith and Pilcher, 1973; Hirons and Edwards, 1986), although other dates of *ca* 5300-5400 BP have been obtained from sites in northern England (e.g.

Bartley *et al.*, 1976; Hibbert and Switsur, 1976). Dates for the event within eastern and north-eastern Yorkshire are also significantly later from upland (frequently *ca* 4700-4800 BP) than lowland sites, suggesting considerable variation in timing within the region (Innes and Simmons, 1988). There is no suggestion that the genus recovered around Gilderson Marr prior to *ca* 4190 BP which compares with records from many other sites in eastern England (e.g. Sims, 1973; Scaife, 1988; Simmons *et al.*, 1993) and beyond (e.g. Hirons and Edwards, 1986), where *Ulmus* shows a comparatively short-lived decline followed by a partial recovery. Although charcoal levels are temporarily reduced after the decline in *Ulmus* (Figure 7.15), fragments are still common, which is unusual (but not unique) with a number of authors having noted a significant drop in charcoal influx after the 'elm decline' (e.g. Bennett *et al.*, 1990; Edwards and MacDonald, 1991; Simmons and Innes, 1996b; Edwards, 1998). This is discussed further in section 10.3.2.

There is considerable evidence for wider vegetational disturbance during GM-6. *Betula* increases in both percentage and absolute terms and *Sorbus*-type, *Rosa* and *Fraxinus excelsior* become consistently present at low levels, perhaps reflecting enhanced flowering due to a decrease in canopy density, or their growth at the woodland edge. Herb diversity also increases and is discussed in detail below. The fact that *Corylus avellana* influx declines at the start of GM-6 suggests that the above changes are not solely a response to declining *Ulmus* levels. This reduction is interesting as the taxon would be expected to benefit from decreased canopy cover. Whether this implies that flowering of the species was reduced by a climatic or anthropogenic mechanism, or that hazel was out-competed by the apparently expanding *Tilia* or *Quercus* populations (Figures 7.15 and 7.17) is uncertain. A re-expansion of *Tilia* coincident with the 'elm decline' has been noted elsewhere in northern England, and explained as reflecting optimal growth conditions for the genus, or a decrease in the proportion of its pollen filtered by trees due to declining canopy density (see Simmons *et al.*, 1993). The consistent presence of *Ilex aquifolium* pollen may indicate its role in a 'regeneration assemblage' (cf. Innes and Simmons, 1988), or could be due to inwash from the soil/litter layer (Pennington, 1979; see also 7.4.1.2). There is also evidence for expansion of the damp-ground and aquatic community during GM-6 with *Frangula alnus, Ranunculus acris*-type and *Sparganium emersum*-type present at low levels. As discussed previously for zone GM-5, this may be a result of increased runoff due to vegetational disturbance.

Whilst the vegetational changes discussed above persist throughout GM-6, on the basis of the pollen, charcoal and LOI records it is possible to separate the zone into two broad phases of landscape history (see Table 7.6). Phase-1 covers the period from *ca* 5430-4960 BP. Although the fluctuations in the arboreal taxa discussed above are similar to those occurring at the opening of GM-5, the percentage LOI curve indicates a steady increase in erosion throughout phase-1 of GM-6. This compares with GM-5, where only the first two levels of the zone potentially show any sign of erosion and even then it is not clear. This suggests that the disturbance event that marks the beginning of GM-6 was either of greater severity than that occurring in GM-5, or located closer to the basin. This is interesting given that herb diversity is only marginally higher during phase-1 of GM-6 than at the opening of GM-5. The lack of a decline in AP:NAP ratios during phase-1 also clearly hides the occurrence of a disturbance event of sufficient enough intensity to cause soil degradation. It is interesting that LOI continues to drop throughout phase-1 (over a period of *ca* 470 ^{14}C years), as even allowing for post-disturbance grazing (cf. Buckland and Edwards, 1984) it is hard to visualise how erosional intensity would increase, and clearance(s) be created (and maintained) over such a long period of time purely by natural means. As previously discussed in chapter 3, it is not possible to separate the effects of one large from several small clearances (also see Edwards, 1979), which in combination with the long duration of this disturbance phase raises the possibility that the signal in the record could be reflecting the combination of a series of discrete disturbance events.

During phase-2 (*ca* 4960-4190 BP), the expanding range of herb taxa, increase in Poaceae undiff. representation and consistently low percentage LOI values (Table 7.6) strongly support an argument for an increase in the intensity (or frequency) of the disturbance regime. Taken as a whole the herb taxa indicate an expansion in the areas of disturbed ground and grassland within the site catchment, or at the least increased disturbance in previously open areas. This shows clearly in the steadily declining AP:NAP ratios, and also the DCA plot (Figure 7.18), with the position of the mean zone score for GM-6 (close to the open ground taxa on the right of the plot) largely due to an increase in herb representation during this phase. The increase in aquatic diversity (Table 7.6 and Figure 7.12) suggests a further rise in the water-table, perhaps due to increased runoff or a change in the climatic regime.

Charcoal levels also increase (cf. phase-1), becoming consistently high which is interesting given the declining representation of heath taxa (particularly *Calluna vulgaris*; Figure 7.16) during GM-6. Even if this does not signify a decrease in the area of heathland within the catchment (and hence a decrease in the area of fire-susceptible vegetation), it is hard to see how natural ignition could occur on a frequent enough basis to account for the sustained charcoal levels. Although an elevated reworked component and a decrease in the number of fragments filtered as a result of canopy opening may account for part of the increase, it is possible that the charcoal record for phase-2 may also be reflecting anthropogenic burning.

It is hard to produce an ecological mechanism that satisfactorily accounts for both the longevity of the vegetational disturbance within GM-6 (even assuming that the record is reflecting the amalgamation of a series of disturbance events), and the high level of erosion evident. Whilst anthropogenic activity may not have been the cause of the initial disturbance, humans perhaps utilising gaps created by the declining *Ulmus* population (*sensu* Brown, 1997b), it is possible that they played a role in maintaining and enlarging the open areas. The presence of large Poaceae pollen throughout the zone also raises the possibility that cultivation of arable crops may have been carried out within the site catchment. It seems reasonable to suggest that the erosion indicated in the palaeoenvironmental record originated from the slopes that surround much of the basin. These slopes are significantly higher than much of the surrounding landscape, and would presumably have been comparatively well-drained and suited to agriculture. During phase-1 the bulk of the large Poaceae grains located were found during low magnification scanning (see chapter 4 for methodology), however, grains were also identified during routine counting during phase-2, suggesting an increasing influx during the latter part of GM-6. If these grains originated from arable crops grown on the slopes around Gilderson Marr, then the increases in herb contribution and diversity, *Pteridium aquilinum* spores, erosion, and large Poaceae influx during phase-2 may reflect an increase in the intensity, or a change in the location, of cultivation. Such activity would certainly account for the soil degradation suggested by the percentage LOI curve.

The problems of separating wild from cultivated grass pollen (investigated in chapter 5 and highlighted in the discussion of GM-5 above), mean that it is not possible to say with any certainty whether the grains located originated from wild grasses (perhaps as part of the expanding wetland flora) or domesticated crops. As a result, whilst the above hypothesis seems feasible, a natural origin for the large grass grains cannot be ruled out. It is also possible that the disturbance events evident during GM-6 resulted from purely natural mechanisms, although given the combination of evidence it seems likely that humans played at least a partial role. There is little direct archaeological evidence for Neolithic activity close to the study site (see Figure 3.12), but artefactual and settlement evidence suggests a human presence within Holderness and the rest of eastern Yorkshire throughout the Neolithic Period (see chapter 2). If the disturbance events evident during GM-6 were to be attributed in part to human activity this would imply a human presence, at least sporadically, within the area for over 1000 ^{14}C years (assuming the reliability of the chronology), thus supplementing the archaeological record.

(iv) Summary

The vegetational record suggests that the landscape surrounding Gilderson Marr was predominately wooded between the early Holocene and *ca* 4190 BP. From *ca* 7220 BP onwards there is evidence for a growing level of vegetational disturbance within the site catchment. Whilst disturbances prior to *ca* 5430 BP had no noticeable effect on soil stability, considerable erosion of the soil layer is indicated between *ca* 5430 BP and 4190 BP. Although natural causes cannot be eliminated entirely, it seems likely that this reflects, at least in part, the activity of humans on the slopes around the basin during the Early and Late Neolithic Periods, and it is possible that arable cultivation was carried out close to the site. The presence of inwashed clay within the sediments of zone GM-6 suggests that the colluvial layer that covers the site may have begun to form as long ago as the Early Neolithic Period.

A summary of the development of the landscape around Gilderson Marr is presented in Table 7.7.

Chapter 8: Sproatley Bog: results and discussion

8.1 Introduction

This chapter presents the results of the analysis of the core obtained from Sproatley Bog. The core is described in detail and the radiocarbon dating programme assessed in sections 8.2 and 8.3. The results of the pollen analyses are then introduced in section 8.4, where deteriorated pollen and local pollen assemblage zones are suggested. Finally, the vegetational development of the catchment is discussed in detail in section 8.5.

8.2 Core description

A detailed description of the core stratigraphy is presented in Table 8.1. The pollen analyses and radiocarbon dating programme suggest that the deposits span part of the Younger Dryas, approximately the first 2500 years of the Holocene, and part of the Historical Period. As the core was not bottomed it is possible that the site contains more extensive Late-Glacial deposits than were recovered. The section of the core between 496 cm and 48 cm was sampled for laboratory analysis.

8.3 Radiocarbon dating

Eleven AMS radiocarbon dates were obtained for the profile, with full details being given in Appendix 6. The date for the earliest *Corylus avellana*-type maximum (9250±100 BP; AA-30879) is significantly too young when compared to dates either side of the event (AA-30878 and AA-30880) and also those for a similar event from the other study sites. Secondly, dates AA-30878, AA-30880 and AA-30881 all overlap at 1 SD and as such are not reliably separable (see Figure 8.1). It is quite possible that these dates lie within the 9500-9600 BP radiocarbon plateau (Kromer and Becker, 1993; Stuiver and Reimer, 1993). As a result, age interpolation during and prior to *ca* 9500-

9600 BP was not felt to be possible with any degree of accuracy, and the accumulation rate diagram presented (Figure 8.18) should be treated with caution. Dates AA-30878 and AA-30879 were not included in the calculation of accumulation rates.

Although dates AA-30882-30884 appear sound, there is evidence for at least three depositional hiatuses between *ca* 250 cm and 150 cm (see section 8.4.1.2), and age interpolations and accumulation rate calculations for this period are subsequently felt to be inaccurate. Dating for this part of the profile is discussed in detail in section 8.4.1.2.

Finally, date AA-30886 (2610 ±50 BP) appears to be too old on palynological grounds. There is no evidence for a depositional hiatus close to this date and it is possible that it is the result of hard-water error, or contamination of the sample with older organic material (perhaps as a result of peat cutting; see 8.4.1.2). If hard-water error is the cause then the possibility arises that dates AA-30887 and AA-30888 (which originate from the same sedimentary unit) are also artificially old. Hard-water error has been recognised from sites north of the study area (e.g. Gilbertson, 1984a), but is perhaps unlikely given that the dates obtained from gyttja earlier in the core (AA-30878-30883) seem unaffected. Date AA-30886 has subsequently been ignored in accumulation rate calculations and age interpolations, which have been tentatively based upon dates AA-30887 and AA-30888. The possibilities of contamination or hard-water error were borne in mind when the pollen record was considered (see section 8.5).

8.4 Pollen data

LDPAZs are prefixed by the initials SBDET and labelled alphabetically, whilst LPAZs are prefixed by the initials SB and labelled numerically. All zones are labelled/numbered from the bottom up.

8.4.1 Deteriorated pollen analysis

8.4.1.1 Local deteriorated pollen assemblage zones (LDPAZs)

The following section describes the LDPAZs that have been assigned to the pollen preservation data. A diagram showing total preservation is presented in Figure 8.2 and a series of diagrams showing the preservation characteristics of the major pollen types are given in Figures 8.3-8.8. Total deterioration percentages are based upon the sum of TLP. Full details of the LDPAZs are given in Table 8.2, and a DCA plot of the mean LDPAZ and deterioration category scores for the first two axes of the ordination is presented in Figure 8.9.

a) SBDET-A: 496-270 cm; Pre-10,200-*ca* 8070 BP (pre 11,520-9030 cal BP)

Pollen preservation is good throughout, with *ca* 5-10 % TLP deteriorated. Breakage is the most important deterioration form at *ca* 2-4 % below 397 cm, increasing slightly to between 5 % and 8 % between 396 cm and 373 cm. Crumpled and amorphous grains are infrequent, rarely exceeding 1.5 %, and with the exception of the samples from below 487 cm, corrosion (undiff.) is generally below 5 % TLP. Indeterminable grains are infrequent, never exceeding 2 % and with no deterioration type dominant.

Percentage LOI is variable within the LDPAZ. Values are initially low at *ca* 5-20 % below 404 cm, but rapidly rise to 70 % between 400 cm and 374 cm. Values are then generally between 70 % and 85 % with the exception of two intervals. Between 359 cm and 349 cm values drop to 45-67 % and levels are also low (18-40 %) between 334 cm and 316 cm. The samples come from within several stratigraphic units. Samples between 496 cm and 406 cm are from sandy clay, those between 404 cm and 306 cm from gyttja and those between 305 cm and 276 cm from peat containing wood fragments. The topmost sample (272 cm) is from peat lacking in wood fragments.

b) SBDET-B: 270-212 cm; *ca* post-8070 BP (*ca* post-9030 cal BP)

Pollen preservation is particularly poor within this zone with deterioration levels rising rapidly from 21.2 % TLP at 268 cm to 73 % at 226 cm. This increase in deterioration is almost entirely due to a rapid rise in corrosion (undiff.), with values increasing from *ca* 15 % to 70 % during the zone. Only occasional pollen grains were located between 222 cm and 212 cm and as they were all severely corroded it is possible that corrosion reached almost 100 % within this section of the core. Amorphous, crumpled and broken grains are present at similar levels to SBDET-A. Indeterminable grains are relatively frequent during the latter half of the zone at 4-7 % TLP, with corrosion (undiff.) dominant.

Percentage LOI is in excess of 85 % throughout and all samples are from within peat.

c) SBDET-C: 212-170 cm; date range unclear

Preservation is much improved through much of this zone with <12 % TLP deteriorated below 188 cm, rising slightly to 15-25 % above 180 cm. The exception to this is the section between 186 cm and 182 cm, where pollen is almost completely absent. Corrosion (undiff.) is greatly reduced through much of the zone at <4 %, but reaches 15.7 % at 180 cm. It is also possible that the absence of pollen between 186 cm and 182 cm is due to severe corrosion. Levels of crumpled and amorphous grains both increase slightly, but rarely exceed 3 % and breakage also increases to *ca* 6-8 % TLP. Indeterminable grains are much reduced at <1.5 % throughout, with no one deterioration form dominant.

Percentage LOI is generally >85 %. Samples below 185 cm are from *Sphagnum*-rich peat and those above 185 cm from undifferentiated peat.

d) SBDET-D: 170-48 cm; *ca* pre-1470-1150 BP (*ca* pre-1360-1030 cal BP)

The zone opens with an increase in total deterioration to *ca* 20-30 % TLP, with preservation fair throughout the zone. Broken and crumpled grains increase in importance to 6-12 % and 4-9 % respectively, but amorphous grains become less frequent than in SBDET-C, rarely exceeding 1% TLP. Corrosion (undiff.) increases to *ca* 8-15 % between 168 cm and 104 cm and decreases slightly to 4-8 % above 100 cm. Indeterminable grains are present at <2.5 % throughout and comprise primarily broken and corroded grains.

Percentage LOI declines steadily from 85 % to 58 % between the start of the zone and 136 cm, stabilises at *ca* 50-58 % between 132 cm and 104 cm and drops again to *ca* 40-48 % above 100 cm. All of the samples are from gyttja with the exception of 168 cm which is from peat.

8.4.1.2 Interpretation

The following section evaluates the main results of the pollen preservation analysis. The discussions centre upon LDPAZs where the preservation data indicate changing taphonomy or that the pollen record may be unreliable or altered in some way. A summary of the analysis is provided in Table 8.3. Specific points, particularly those relating to individual pollen types, will also be drawn upon in section 8.5 to aid the discussion of the vegetational record.

(i) SBDET-A; Pre-10,200-*ca* 8070 BP (pre 11,520-9030 cal BP)

The percentage LOI curve suggests that the period prior to *ca* 10,200 BP was characterised by considerable erosion, which in combination with the abundance of Pre-Quaternary microfossils throughout the Younger Dryas clays (data not presented) raises the possibility that part of the pollen assemblage may have been reworked. There is no clear evidence of this in the pollen preservation data, however, suggesting either that a low proportion of the pollen component was the result of inwash, or that minimal damage occurred during inwashing. The preservation data overall indicate that the pollen record is sound throughout this period.

(ii) SBDET-B: *ca* post-8070 BP (*ca* post-9030 cal BP)

Deterioration increases markedly after *ca* 8070 BP, predominately due to a sharp increase in the proportion of grains that are corroded (Figure 8.2). The trend of increasing corrosion culminates between 222 cm and 212 cm (perhaps *ca* 7380 BP) when pollen becomes present at trace amounts only, with all grains severely corroded. It is possible that a depositional hiatus occurred within the core somewhere between *ca* 222 cm and 212 cm (perhaps at 222 cm), resulting in the exposure of this part of the profile to oxygenated conditions for a significant period of time. Loss of pollen through corrosion as a result of drying of the deposit after (and perhaps also during) deposition is likely to have occurred. Pteropsida (monolete) undiff. levels increase significantly during this LDPAZ and whilst some of the input may be from ferns growing upon the peat surface, it is likely that the spores were artificially concentrated due to their high corrosion resistance (Pennington, 1965). The pollen preservation data thus suggest that the pollen record between 270 cm and 212 cm is unreliable and it is possible that distortion of the record may have occurred due to the almost complete, or complete, loss of susceptible pollen types. The poor dating controls within this part of the core mean that it is not possible to assign a duration to the proposed hiatus, but it seems likely to have occurred prior to the *Alnus* rise and after *ca* 8000-7500 BP (see Figures 8.10 and 8.15).

(iii) SBDET-C: date range unclear

Pollen preservation is much improved between 212 cm and 188 cm (i.e. for much of SBDET-C) and although it is not possible to assign an accurate date range to this section of the profile, it is clearly pre-*Alnus* rise in age (Figure 8.10). Whilst the above part of the pollen record appears reliable, the presence between 186 cm and 182 cm of only trace levels of highly corroded pollen raises the possibility that a second depositional hiatus may have occurred. This is supported by the abrupt change in the pollen spectra above 180 cm, and it is likely that the proposed hiatus occurred prior to 6650±65 BP (AA-30885).

(iv) SBDET-D: *ca* pre-1470-1150 BP (*ca* pre-1360-1030 cal BP)

The pollen record between 180 cm and 168 cm (i.e. the latter part of SBDET-C and the earliest part of SBDET-D) is post-*Alnus* rise, but pre-major clearance in age on palynological grounds, however the record above 168 cm appears to be Early Medieval or later in date (see section 8.5). This coincides with the depositional change from peat to gyttja (Table 8.1). Although there is an age discrepancy between the samples at 168 cm and 164 cm of at least 4500 radiocarbon years, there is no evidence within the pollen preservation data to suggest that this section of the core was exposed to oxygenated conditions for a significant period of time (as has previously been argued above). Whilst this does not necessarily disprove the existence of a prolonged depositional hiatus in the profile it is hard to see how no net sediment accumulation, soil formation or pollen corrosion could occur over such a long time-period. It is also difficult to envisage how open water conditions of up to 1.5 m in depth could become re-established in the basin naturally given the topography of the site (Figure 3.14). It is perhaps more likely that the upper section of the peat unit was removed prior to (or during) the Early Medieval period, when the site re-flooded and conditions of open-water were re-established. Peat cutting for fuel is one possible explanation, but an alternative hypothesis is that a pit was dug for the purposes of retting hemp (*Cannabis sativa*) or flax (*Linum usitatissimum*), as discussed in detail in section 8.5. Such a pit is likely to have been of limited areal extent and the pollen record during SB-7 may subsequently reflect a very local landscape.

Two other points are of interest concerning zone SBDET-D. Firstly, the curves for the main pollen (and to an extent deteriorated pollen) types along with percentage LOI fluctuate between 164 cm and 148 cm, but are relatively stable from 146 cm onwards (see Figures 8.19, 8.20 and 8.23). The date of 2610±50 BP (150.5-152.5 cm; AA-30886) also seems too old on palynological grounds (see section 8.3). It may be that mixing of older disturbed peat (as a result of the possible peat digging discussed above), with relatively more recent gyttja and pollen, occurred between 164 cm and 148 cm as the sediments of the basin bottom and edges consolidated. Such mixing could account for the minor fluctuations in the pollen and pollen preservation records and also the age of the radiocarbon date.

Secondly, pollen preservation is only moderately good throughout this period with *ca* 20-30 % TLP deteriorated, and broken and crumpled grains at their highest representation. This contrasts with the Late-Glacial and earliest Holocene sections of the profile where broken, crumpled and also corroded grains were comparatively infrequent, despite the landscape being of similar overall openness (see the AP:NAP ratios in Figures 8.13 and 8.23) and the basin containing open-water (the samples originating from broadly similar depositional units of gyttja/clay). Erosion levels were also higher for much of these periods than in the Historical Period. This suggests that the degree of mechanical and chemical damage is not linked to erosion level or landscape openness *per se,* but that the exact type of landscape, modes of pollen recruitment and perhaps also climatic regime are of importance in determining pollen preservation state. Despite the relatively high levels of broken and crumpled grains, the high palynological diversity and the fact that deterioration is only moderate for all pollen types suggest that the pollen record for this period is sound, although the long-distance and inwashed components may be comparatively higher than in SBDET-B, SBDET-C and the latter part of SBDET-A.

(v) General points

The evidence for at least two depositional hiatuses during SBDET-B and SBDET-C, the high levels of corrosion throughout SBDET-B and the truncation of the record at the start of SBDET-D, suggest that the pollen record is incomplete and unreliable between *ca* 270 cm and 168 cm. This covers the upper part of SB-4, SB-5 and SB-6 and the vegetational records for these LPAZs are subsequently not discussed in detail in section 8.5.

8.4.2 Local pollen assemblage zones (LPAZs)

This section describes the LPAZs that have been assigned to the pollen data. To take into account the evidence of a prolonged depositional hiatus between *ca* 168 cm and 164 cm (discussed above) and to accommodate the large number of samples analysed from the core, the pollen data have been separated into two sections in the diagrams presented. Percentage diagrams showing samples between 496 cm and 168 cm are presented in Figures 8.10-8.14, whilst diagrams for samples between 164 cm and 48 cm are shown in Figures 8.19-8.23. Summary concentration and accumulation rate diagrams are presented in Figures 8.15-8.18, 8.24 and 8.25.

Details of the LPAZs are given in Table 8.4 and a DCA plot of the mean taxon and mean LPAZ scores for the first two axes of the ordination is shown in Figure 8.28.

a) SB-1: 496-405 cm; *ca* pre-10,200-10,200 BP (*ca* pre-11,520-11,520 cal BP)

This zone covers the lowest section of the core that was analysed for pollen. Non-arboreal taxa dominate the record with total herb pollen at *ca* 40-75 % TLP throughout the zone. *Betula* is the dominant arboreal genus at *ca* 20-50 %, and *Salix* is consistently present at 5-8 %. *Pinus sylvestris* and *Juniperus communis* are also present in most levels at <5 % TLP. Poaceae undiff. representation fluctuates between 30 % and 60 %, and Cyperaceae undiff. declines from 42.4 % at 496 cm to <10 % TLP for much of the zone. Herb diversity is high with *Ranunculus* acris-type, *Artemisia*-type, Chenopodiaceae undiff., *Rumex acetosa, R. acetosella* and *Thalictrum* frequent. *Calluna vulgaris* pollen occurs at low levels, as does *Empetrum nigrum* between 460 cm and 432 cm. A relatively diverse aquatic flora is suggested with taxa including *Nymphaea alba, Sparganium emersum*-type and Potamogetonaceae undiff. *Equisetum* spores are frequent with peaks of 18.9 % and 23.2 % TLP at 480 cm and 448 cm respectively, and *Sphagnum* and Pteropsida (monolete) indet. spores are present throughout at <2 %.

Percentage LOI is low at *ca* 10-25 % and both spherule to exotic ratios and charcoal levels are extremely high. Pollen preservation is good with *ca* 5-10 % TLP deteriorated, the zone being covered by SBDET-A. Total pollen and spore concentrations are initially very low at *ca* 31,000 grains cm^{-3}, but increase to between 100,000 and 200,000 grains cm^{-3} and total influx values range from 2000-10,000 grains cm^{-2} yr^{-1}.

b) SB-2: 405-372.5 cm; *ca* 10,200-9570 BP (*ca* 11,520-10,830 cal BP)

The zone opens with a rapid rise in *Betula* representation, the genus accounting for *ca* 70-80 % TLP between 404 cm and 388 cm and around 60-65 % for the rest of the zone. *Pinus sylvestris* and *Salix* are present at 2-6 % and 4-9 % TLP respectively and *Quercus, Ulmus, Viburnum* and *Sorbus*-type occur in many levels at <2 %. *Corylus avellana*-type expands above 392 cm, reaching 37.7 % at 373 cm and *Juniperus communis* pollen is absent. *Calluna vulgaris* and *Vaccinium*-type are present at low levels and herb pollen remains diverse, although Poaceae undiff. and Cyperaceae undiff. are reduced to *ca* 10-20 % and <2 % TLP respectively. The aquatic and spore components remain similar to SB-1 with the addition of *Nuphar lutea,* and a decline in *Equisetum* representation to <2 %.

Percentage LOI steadily increases, reaching 70 % at the end of the zone and charcoal levels decline, but remain high. Spherule to exotic ratios are moderately high and pollen preservation is similar to SB-1, the zone also being covered by SBDET-A. Total pollen and spore concentrations increase to *ca* 200,000-300,000 grains cm^{-3} and total influx is between 10,000 and 17,000 grains cm^{-2} yr^{-1}.

c) SB-3: 372.5-315.5 cm; *ca* 9600/9500-8980 BP (*ca* 10,870/10470-10,180 cal BP)

Four subzones are suggested for this zone. The dating problems discussed in section 8.3 mean that it is not possible to assign an age range to subzones SB-3(a) and SB-3(b), but it is likely that both subzones are covered by the 9500-9600 BP radiocarbon plateau (*ca* 10,870-10,470 cal BP).

i) SB-3(a): 372.5-357.5 cm

The subzone opens with the rapid expansion of *Corylus avellana*-type to >75 % TLP. *Betula* representation decreases concomitantly, the genus occurring at <25 % for much of the zone, and *Pinus sylvestris* declines to <2 %. *Salix* is also reduced and *Sorbus*-type pollen is absent. The other arboreal types are present at similar levels to the preceding zone. Ericaceous pollen only occurs sporadically and herb diversity declines, with taxa such as *Filipendula* and *Ranunculus acris*-type infrequent and total herb pollen accounting for only 2-4 % TLP. The spore component is similar to SB-2, but aquatic input is reduced, with *Nuphar lutea* absent and *Nymphaea alba* and Potamogetonaceae undiff. infrequent.

Percentage LOI is high at >80 %, charcoal levels are very low and spherule to exotic ratios are similar to SB-2. Pollen preservation remains good, the subzone being covered by SBDET-A and total pollen and spore concentrations increase markedly to *ca* 300,000-600,000 grains cm^{-3}. Total influx varies between *ca* 15,000 and 35,000 grains cm^{-2} yr^{-1}.

ii) SB-3(b): 357.5-347.5 cm

A number of changes occur within this subzone. *Corylus avellana*-type drops to 14.8 % at 357 cm and gradually recovers to 59.8 % TLP at the end of the zone and *Betula* increases to a maximum of 59.6 % at 357 cm, decreasing as *Corylus avellana*-type recovers. *Pinus sylvestris* and *Salix* occur at similar levels to SB-2 and *Quercus, Ulmus* and *Viburnum* are present throughout at low levels. Pollen from Ericaceous taxa is absent during the zone. Total herb pollen increases markedly to *ca* 6-15 % TLP with Poaceae undiff. the most frequent non-woody pollen type at *ca* 4-10 %. Herbaceous diversity also increases with *Ranunculus acris*-type, *Filipendula, Artemisia*-type and *Achillea*-type present at <2 % at most levels. Spore levels are similar to the preceding zone, but there is an increase in aquatic diversity with taxa including *Nymphaea alba* and *Nuphar lutea* becoming more frequent.

Percentage LOI declines to *ca* 60 %, charcoal levels increase and spherule to exotic ratios are similar to SB-3(b). Pollen preservation remains good, the subzone being covered by SBDET-A. Total pollen and spore concentrations drop to 200,000-300,000 grains cm^{-3} and total influx is generally *ca* 10,000-20,000 grains cm^{-2} yr^{-1}.

iii) SB-3(c): 347.5-334.5 cm; *ca* 9590-9290 BP (*ca* 10,830-10,470 cal BP)

The subzone opens with the recovery of *Corylus avellana*-type to >75 % and the decline of *Betula* to <25 % TLP. *Salix* and *Pinus sylvestris* are reduced in representation to <2 % at most levels and the other arboreal taxa remain present at similar levels to SB-3(b). Heath taxa are represented by a single grain of *Vaccinium*-type at 345 cm and herbaceous pollen input decreases, the herb record being similar to that of SB-3(a). Aquatic input and diversity also declines although *Myriophyllum verticillatum* is present at two levels. *Sphagnum* spores are absent but the spore record is otherwise similar to that of the preceding subzone.

Percentage LOI recovers to above 80 % and spherule to exotic ratios are similar to SB-3(b). Pollen preservation remains good and charcoal levels are reduced to similar values to those of SB-3(a). Total pollen and spore concentrations increase during this subzone to between *ca* 400,000 and 700,000 grains cm^{-3} and total influx is *ca* 20,000-40,000 grains cm^{-2} yr^{-1}.

iv) SB-3(d): 334.5-315.5 cm; *ca* 9290-8980 BP (*ca* 10,470-10,180 cal BP)

Corylus avellana-type declines at the opening of the zone to fluctuate between 52 % and 62 % and *Betula, Pinus sylvestris* and *Salix* increase in representation to *ca* 25-30 %, 2-5 % and 2-6 % respectively. *Viburnum, Quercus* and *Ulmus* continue at similar levels to the preceding subzone. Total herb pollen increases to *ca* 5-12 % with Poaceae undiff. at 2-6 % throughout the zone. Herbaceous diversity also increases becoming broadly similar to that of SB-3(b) with the addition of low levels of *Plantago major/media* and

Thalictrum. The aquatic record is to SB-3(b), and *Equisetum* is present at *ca* 2-4 % prior to 329 cm. *Polypodium* and *Pteridium aquilinum* spores also occur sporadically.

Percentage LOI drops to 42.1 % at 334 cm and steadily declines as the subzone progresses, reaching a minimum of 21.1 % at 316 cm. Charcoal levels increase markedly (cf. SB-3[c]) becoming moderate to high with maxima at 333 cm, 326 cm and 318 cm. Spherule to exotic ratios and pollen preservation are similar to the preceding subzone. Total pollen and spore concentrations drop to *ca* 150,000-200,000 grains cm^{-3} and total influx is generally between 10,000 and 15,000 grains cm^{-2} yr^{-1}.

d) SB-4: 315.5-218 cm; *ca* post-8980 BP (*ca* post-10,180 cal BP)

The dating problems discussed in section 8.3 mean that an end date cannot be reliably assigned to this subzone.

Ulmus rapidly expands, stabilising at *ca* 5-10 %, and *Quercus* steadily increases from <2 % at 315 cm to 15.3 % at 296 cm. *Betula* declines from 15.3 % at 315 cm to <10 % TLP, *Corylus avellana*-type is relatively stable at *ca* 60-75 %, and *Pinus sylvestris* is present in most levels at <4 %. Pollen from *Fraxinus excelsior, Hedera helix* and *Salix* is consistently present at low levels and *Alnus glutinosa* occurs sporadically. *Viburnum* is present in the lower part of the zone only and *Calluna vulgaris* occurs in several samples. The herb component is much reduced with Cyperaceae undiff. the main contributor at *ca* 4-10 % between 272 cm and 238 cm. Total herb pollen never exceeds 10 % TLP, aquatic pollen is sparse and *Equisetum* and *Sphagnum* spores are infrequent. *Pteridium aquilinum* and *Polypodium* spores occur occasionally and there is a marked increase in Pteropsida (monolete) indet. above 272 cm, peaking at 469 % TLP at 242 cm.

Percentage LOI is stable at >80 % and charcoal levels are very low, fragments being absent from several levels. Spherule to exotic ratios are initially similar to SB-3(d), but decline above 238 cm to become very low by the end of the zone. Pollen preservation is initially good, but becomes very poor above 270 cm and the zone is covered by the upper part of SBDET-A and SBDET-B. Total pollen and spore concentrations increase to *ca* 300,000-500,000 grains cm^{-3} at the start of the zone and rise to >800,000 grains cm^{-3} above 238 cm. Total influx is variable, but initially *ca* 15,000 grains cm^{-2} yr^{-1}, increasing to *ca* 500,000 grains cm^{-2} yr^{-1} above 242 cm.

e) SB-5: 218-184 cm; date range unclear

The zone opens with the steady decline of *Corylus avellana*-type from 65 % at 210 cm to 34.3 % at 188 cm. *Betula* fluctuates, but peaks at 49.9 % at 188 cm and *Tilia* is present in most levels at <2 %. Representation of the other arboreal taxa is broadly similar to the preceding zone, although *Ulmus* decreases slightly to *ca* 2-4 % TLP. Ericaceous pollen is sparse and herb diversity and contribution continues to decline, with Cyperaceae the most frequent taxon at *ca* 4-8 %. Pollen and spores from aquatics, *Pteridium aquilinum* and *Equisetum* are absent. Pteropsida (monolete) indet. spores are present at <17 % throughout and *Sphagnum* reaches its highest representation at >13 % (peaking at 96 % TLP at 188 cm).

Percentage LOI is stable and high, spherules are absent and charcoal levels are very low. Pollen preservation is variable, but generally good, the zone being covered by SBDET-C. Total pollen and spore levels decline to *ca* 50,000 grains cm^{-3} at 206 cm, but recover to *ca* 200,000-300,000 grains cm^{-3} above this and total influx is highly variable at between 4,000 and 20,000 grains cm^{-2} yr^{-1}.

f) SB-6: 184-162 cm; date range unclear

The dating problems discussed in section 8.3 mean that dates cannot be reliably assigned to this zone.

Alnus glutinosa is present at between 10 % and 30 % throughout, *Quercus* increases in representation to *ca* 20-40 % and *Betula* declines to below 10 % (frequently being <3% TLP). *Corylus avellana*-type fluctuates between 10 % and 40 %, *Pinus sylvestris* never exceeds 2 % TLP and the other arboreal taxa are present at similar levels to SB-5. Heath representation increases with *Calluna vulgaris* and *Vaccinium*-type present at <2 % in several levels. Herb diversity also increases with Apiaceae undiff., Brassicaceae undiff.

and Lactuceae undiff. present towards the top of the zone. Aquatic pollen is absent with the exception of an isolated occurrence of *Sparganium emersum*-type and Pteropsida (monolete) indet. spores are present at similar levels to the preceding zone. Both *Polypodium* and *Sphagnum* are present throughout at <2 % TLP.

Percentage LOI is generally >80 %, but drops to 36.4 % at 160 cm. Spherule to exotic ratios are similar to SB-4 and charcoal levels are variable, but generally low. Pollen preservation is good to moderate, the zone being covered by the upper part of SBDET-C and the lower part of SBDET-D. Total pollen and spore concentrations are initially high, but drop to *ca* 100,000-200,000 grains cm^{-3} towards the end of the zone and total influx varies between 700 and 19,500 grains cm^{-2} yr^{-1}.

g) SB-7: 162-48 cm; *ca* pre-1470-1150 BP (*ca* pre-1360-1030 cal BP)

Two subzones are suggested for this zone:

i) SB-7(a): 162-96.5 cm; *ca* pre-1470-1470 BP (*ca* pre-1360-1360 cal BP)

This subzone is dominated by herbaceous pollen which accounts for *ca* 40-70 % TLP. *Betula* and *Quercus* are present at <5 % and *ca* 4-15 % respectively, and *Corylus avellana*-type and *Alnus glutinosa* are both present at *ca* 8-15 %. *Salix, Fraxinus excelsior, Tilia, Ulmus* and *Pinus sylvestris* occur in most samples at <2 %, and *Acer campestre*-type and *Fagus sylvatica* pollen occur sporadically. Ericaceae frequencies are similar to SB-6 and Poaceae undiff. occurs at *ca* 25-40 % TLP throughout the subzone. The herb flora is very diverse and includes large Poaceae pollen, Caryophyllaceae undiff., Chenopodiaceae undiff., Lactuceae undiff., *Rumex acetosella* and *Centaurea nigra* in most levels. *Plantago lanceolata* pollen is consistently present at *ca* 2-10 % and *Cannabis*-type also occurs at *ca* 2-5 % above 136 cm. There is a big increase in the representation of aquatic species with *Hydrocotyle vulgaris, Menyanthes trifoliata, Sparganium emersum*-type and Potamogetonaceae undiff. frequent. *Myriophyllum verticillatum* expands markedly above 132 cm, peaking at 64.9 % TLP at 98 cm. The spore record is largely similar to the preceding zone, although *Equisetum* and *Pteridium aquilinum* spores occur in most levels at <2 %.

Percentage LOI is initially low at <35 %, rises to 74 % at 154 cm and then steadily declines to *ca* 40-45 % towards the end of the subzone. Charcoal levels are relatively high and stable, whilst spherule to exotic ratios are variable, but slightly reduced (cf. SB-6). Pollen preservation is moderate and the subzone is covered by SBDET-D. Total pollen and spore concentrations are similar to the preceding zone and total influx is low at *ca* 1000-9000 grains cm^{-2} yr^{-1}.

ii) SB-7(b): 96.5-48 cm; *ca* 1470-1150 BP (*ca* 1360-1030 cal BP)

A number of changes occur at the start of this subzone, particularly within the herbaceous component. *Betula* occurs at <4 % and *Alnus glutinosa* and *Quercus* are slightly reduced at *ca* 4-8 % and *ca* 5-8 % respectively. The other arboreal species and Ericaceous taxa occur at similar levels to the preceding subzone. Poaceae undiff. representation also remains relatively unchanged, but Cyperaceae undiff. increases, peaking at 22.9 % TLP at 62 cm. There is a slight increase in overall herb diversity with *Centaurea cyanus, Alchemilla*-type, *Oxyria*-type and *Urtica* present at many levels. *Cannabis*-type increases to >30 % TLP between 96 cm and 80 cm, declining to *ca* 6-12 % thereafter and representation of large Poaceae grains increases to >2 % TLP at most levels. Aquatic pollen increases in abundance with *Myriophyllum verticillatum* peaking at 87.7 % TLP at 80 cm, and *M. alterniflorum* expanding to reach 11.6 % at 48 cm. *Equisetum* increases to *ca* 5-10 % TLP above 76 cm. *Sphagnum* becomes infrequent and the other spore taxa remain relatively unchanged (cf. SB-7[a]).

Percentage LOI is stable at *ca* 40-45 %, charcoal levels are moderate and spherule to exotic ratios are initially similar to SB-7(a), but decline above 76 cm. Pollen preservation remains moderate, the subzone being covered by SBDET-D. Total pollen and spore concentrations are similar to the preceding subzone and total influx is *ca* 18,000-25,000 grains cm^{-2} yr^{-1}.

8.5 Vegetational history

This section is organised according to the approximate cultural periods defined in Appendix 1. This has been done to allow the vegetational record to be viewed in the context of human cultural development within eastern Yorkshire.

(i) The Upper Palaeolithic; pre-10,200-*ca* 10,200 BP (pre-11,520-11,520 cal BP)

The pollen record and core stratigraphy suggest that the LPAZ SB-1 covers part of the Younger Dryas Stadial. This places a maximum date for the base of the zone as *ca* 11,000 BP and there are at least 1.36 m of unsampled deposits below this. The high clay component within this section of the profile indicates that the landscape was characterised by considerable levels of erosion, with the sand fraction perhaps the result of deposition within a relatively high energy environment. An alternative possibility is that the sand within the profile is the result of aeolian transport, as has previously been argued for the nearby site of Gransmoor by Walker *et al.* (1993).

Betula was the dominant arboreal taxon during SB-1 at *ca* 20-40 % TLP. The size-frequency diagram for 492 cm (presented in Figure 8.29) has a distribution centred upon *ca* 14-15 µm and as Mäkelä (1996) reports that *B. nana* has a mean grain size of *ca* 16 µm, it seems likely that the bulk of the *Betula* pollen from this level originates from dwarf birch. This contrasts with the size-frequency diagrams for 484 cm and 440 cm which show distributions centred upon *ca* 20-21 µm and *ca* 22-23 cm respectively (comparable with the pollen sizes of tree birches; *ibid*). Whilst some of this input may be the result of long-distance pollen transport (which is likely to have been considerable in such an open landscape) or reworking (see 8.4.1.2), it is probable that limited areas of tree birch occurred close to the site at these levels. The hypothesis that tree birches were present in central Holderness during the Younger Dryas is supported by the finds of tree birch macrofossils from Skipsea Withow Mere, northern Holderness dated 10,710±70 BP (Q-3035) and 10,440±80 BP (SRR 1943; Hunt *et al.*, 1984; see also section 2.3.1.1). Although the size-frequency data does not clearly indicate the presence of *B. nana* in the samples from 484 cm and 440 cm, it is possible that the species remained present as a low-lying shrub through much of the Younger Dryas (as has previously been argued at The Bog at Roos [Beckett, 1975; 1981] and Gransmoor [Walker *et al.*, 1993]), but that its pollen was swamped by that of the tree birches.

The apparent change in the predominant species of *Betula* above 492 cm is interesting, particularly when the palaeoenvironmental data is considered as a whole. Below 487 cm, birch representation is lower, Cyperaceae undiff. representation higher and percentage LOI considerably lower than during the rest of SB-1. In combination with the *Betula* size data this may suggest that environmental conditions were unfavourable for tree birch growth during the period covered by samples 492 cm and 496 cm, with the increase in *Betula* representation above 487 cm reflecting the expansion of tree birches as climatic or soil conditions became more favourable. Any conclusions must remain tentative, however, in view of the low number of samples below 487 cm and the fact that *Betula* grain sizes were only measured from three sample levels within SB-1.

Whilst *Salix* was relatively abundant during SB-1, possibly as a mixed *Betula-Salix* scrub, and *Juniperus communis* occurred at low levels, the pollen data (Figures 8.10-8.12) suggest that the vegetation around Sproatley Bog was dominated by non-woody taxa throughout the zone, as emphasised by the extremely low AP:NAP ratios of <1:1 (Figure 8.13). The abundance of light-demanding and disturbed ground herbs such as *Artemisia*-type, Chenopodiaceae undiff., *Thalictrum* (possibly *T. alpinum* and/or *T. minus*; cf. Day, 1995), *Rumex acetosa* and *R. acetosella*, along with the high levels of Poaceae undiff. pollen suggest that open grassland dominated the vegetational landscape. Although the climate of the Younger Dryas in eastern England is likely to have been very cold and dry (Buckland, 1982; Walker *et al.*, 1993), the presence of significant levels of *Filipendula, Ranunculus acris*-type and *Equisetum* pollen during SB-1 (Figures 8.11 and 8.12) indicate that damp-ground communities formed important elements of the catchment vegetation. Limited areas of heath are also suggested by the presence of *Calluna vulgaris* and *Empetrum nigrum* pollen.

Charcoal levels are extremely high throughout SB-1, particularly below 484 cm. As previously discussed in the context of the Early Holocene at Cess Dell and Gilderson Marr (sections 6.5 and 7.5) much of this input may be the result of reworking, although some natural burning of the steppe/open scrub vegetation is also likely to have occurred given the hypothesised dry conditions of the period (Walker *et al.,* 1993). The high charcoal levels contrast markedly with the record from Star Carr, where fragments are scarce (Day, 1995; Dark, 1998b). This is interesting given that clays form an important component of both the Sproatley Bog and Star Carr profiles during the Younger Dryas and that extensive soil erosion is indicated in both cases (see also Dark, 1998b). The cause of this contrast is unclear, but is perhaps related to differences in the burning regime around the site prior to, or earlier within, the Younger Dryas (hence soil charcoal levels). One possibility is that the charcoal record is reflecting variation in human activity between the two sites (cf. section 10.3.2). In order to account for the consistently high levels of charcoal within the Sproatley Bog profile, significant levels of anthropogenic burning would need to have occurred. Charcoal levels are also high during the terminal Younger Dryas/earliest Holocene records from the other sites investigated as part of this project, and it is again likely that the majority of the input reflects fragments eroded from catchment soils. If a similar argument is applied to these sites, then the data suggest a high level of anthropogenic burning throughout central Holderness at some stage during the Late-Glacial. Whilst possible, this is perhaps unlikely and it would be unwise to infer high levels of Upper Palaeolithic activity purely on the basis of the charcoal record, particularly given the probability that the fragments are reworked. It is perhaps more likely that the data indicate differences in natural burning regimes between Star Carr and central Holderness during or prior to the Younger Dryas.

A final possibility is that the charcoal may have originated from the Late-Devensian till deposits that cover much of eastern Yorkshire, the differences in charcoal levels between sites perhaps being related to slight differences in till composition. Although the charcoal quantification techniques used in this study differ from those employed in the analysis of the Star Carr profile it is unlikely that this is the cause of the difference.

(ii) The Early Mesolithic; *ca* 10,200-8600 BP (11,520-9580 cal BP)

The marked increase in *Betula* representation at the opening of SB-2 (Figures 8.10 and 8.15) is likely to be a response to climatic amelioration at the start of the Holocene, with the stratigraphical change from clay to gyttja and rise in the percentage LOI curve (Figure 8.13) indicating that the soils of the catchment rapidly stabilised during the Early Holocene. It is possible that the increase in sediment organic content is also reflecting increased autochthonous organic matter production. There is no palynological evidence for a depositional hiatus at the Late-Glacial/Holocene boundary and it is likely that the site contains a full Early Holocene record.

Betula dominates the pollen record for much of SB-2 (Figures 8.10 and 8.15), with the size-frequency data (Figure 8.29) showing no discernible *B. nana* input. The poor dating controls for the Early Holocene section of the profile (see section 8.3) mean that it is not possible to estimate the duration of this expansion, but it seems likely that birch woodland formed the dominant vegetation type between *ca* 10,200-10,000 BP and *ca* 9600 BP. The relatively high representation of *Salix* (at *ca* 4-9 % throughout the zone) suggests that the genus was also common, whilst the absence of *Juniperus communis* pollen may reflect its competitive displacement by the expanding *Betula* and perhaps *Salix* populations. Pollen from *Quercus* and *Ulmus* is present at low levels throughout SB-2, but it is likely that this reflects long-distance transport rather than limited local growth. This is supported by the pollen preservation data, with the bulk of the pollen from the two genera being deteriorated (Figures 8.5 and 8.6). Although *Pinus sylvestris* pollen is present at *ca* 2-6 % TLP it is probable that much of this input is also due to long-distance transport with the species likely to have been scarce or absent from the catchment during the Early Holocene (see section 6.5 for a more complete discussion).

The wide diversity of open ground herbs (e.g. *Achillea*-type, *Artemisia*-type and *Rumex acetosella*) and the presence of Poaceae undiff. at *ca* 10-20 % TLP suggest that the woodland canopy was relatively open, as previously argued for Cess Dell and Gilderson Marr (sections 6.5 and 7.5). This is supported by the AP:NAP ratios, which although increased (cf. SB-1) remain low (Figure 8.13). Although *Filipendula* representation is reduced (cf. SB-1) the absolute data suggest that this is largely a proportional effect due to the increase in *Betula* pollen influx (see Figure 8.15) and it is likely that tall herb communities persisted within the catchment. In conjunction with the presence of *Ranunculus acris*-type this may indicate the occurrence of areas of damp grassland. The low levels of *Calluna vulgaris* and *Empetrum nigrum* suggest that limited heath communities also occurred within the pollen catchment, and the presence of Pteropsida (monolete) indet. spores suggest that ferns occurred within the understorey.

As at the other study sites charcoal influx is very high during the earliest Holocene, but rapidly declines as percentage LOI increases. This suggests that much of the input may have been the result of erosional inwash, although it is possible that natural burning of the open birch woodland also occurred.

From *ca* 9570±75 BP (AA-30878) *Corylus avellana*-type pollen increases in representation. As previously discussed in section 6.5 it seems safe to assume that much, if not all, of this input originated from *Corylus avellana* rather than *Myrica gale*, and it will be treated as such in the following discussions. The absolute data suggest that *Corylus avellana* was locally present for much of SB-2 (i.e. above 390 cm), with major expansion occurring during the latter part of SB-2 and the earlier part of SB-3(a) (between the depths of 376 cm and 365 cm). Although the dating problems for this period mean that a duration for the event cannot be estimated, on the basis of the discussion in section 8.3 it is likely that the expansion occurred entirely within the 9500-9600 BP radiocarbon plateau (Kromer and Becker, 1993; Stuiver and Reimer, 1993).

The concentration data suggest that the *Corylus* expansion occurred at the expense of *Betula*, with birch probably declining due to competitive exclusion. Poaceae undiff. representation and herbaceous diversity decrease (Figures 8.11 and 8.12) as zones SB-2 and SB-3(a) progress suggesting an increase in canopy density, or a decline in the proportion of open ground within the catchment. This is supported by the increasing AP:NAP ratios (Figure 8.13). Charcoal concentrations also decline with fragments becoming particularly scarce during SB-3(a), see Figures 8.13 and 8.14. It is probable that this is a reflection of decreasing erosional input and vegetation flammability, and greater filtration of fragments by the increasing canopy density (cf. Hirons and Edwards, 1990).

Whilst the percentage and absolute data suggest that *Corylus avellana* woodland formed the dominant vegetation type during SB-3(a), with the pollen type present at *ca* 70-80% TLP throughout the subzone, a number of changes occur during SB-3(b). *Corylus avellana*-type drops from 77.5 % TLP at 358 cm to 14.8 % at 357 cm and *Betula* (probably tree birch; Figure 8.29), Poaceae undiff. and open ground herbs increase in representation (see Figure 8.14), suggesting a switch in the dominant vegetation type from *Corylus avellana*- to open *Betula*-woodland. A similar contraction in the *Corylus avellana*-type curve is seen within the Early Holocene profiles from Cess Dell and The Bog at Roos and it is possible that it reflects a period of climatic deterioration, most probably the Pre-Boreal Oscillation (PBO; *sensu* Björck *et al.*, 1997; as discussed in detail in section 6.5).

The clarity of the palynological changes within the Sproatley Bog profile and the application of 1 cm contiguous sampling (cf. every 2 cm at Cess Dell and The Bog at Roos) facilitate the detailed reconstruction of the vegetational and wider environmental conditions within the site catchment during the period. Although the dating uncertainties for the Early Holocene section of the profile (see 8.3) mean that the accumulation rate data need to be interpreted carefully, the changes in influx for the major taxa mirror those observed in the percentage record suggesting that the data are reliable.

A number of points can be made. Firstly the drop in *Corylus avellana*-type representation and influx occurs within 1 cm (Figures 8.14 and 8.17), suggesting that the decline in *Corylus avellana* pollen production occurred very rapidly. A similarly rapid response is observed for *Betula*, and although it is not possible to assign an exact duration to the changes, they are likely to have occurred within *ca* 5-20 years. It is likely that the decline in *Corylus avellana* representation was due to a population decline, rather than decreased flowering with the extremely low representation and influx between 357 cm and 354 cm suggesting that the taxon was almost completely or totally lost from the pollen catchment. This hypothesis is supported by the recovery in *Corylus avellana* representation (and influx) above 354 cm, which is very similar in pattern (and apparent rate) to the initial expansion during SB-2 (see Figures 8.14, 8.16 and 8.17), perhaps suggesting that gradual re-colonisation of the area occurred rather than the re-expansion of an existing (local) population. The sharpness of the palynological changes at the opening of SB-3(b) suggest that little mixing occurred within the deposit.

The environmental conditions of the period favoured a very similar vegetation composition to that of the upper part of SB-2, as shown by the proximity of zones SB-2 and SB-3(b) in the DCA plot (Figure 8.28). The increased influx of *Filipendula, Equisetum* and *Ranunculus acris*-type probably signifies the expansion of damp grassland, although the changes may in part be the result of decreased filtering of pollen due to the decline in canopy density. Although *Salix* and *Pinus sylvestris* increase in representation, the absolute data suggest that the increases are largely proportional due to the decline in *Corylus avellana* input. It is likely that the slight increase in charcoal levels is due to a decrease in the number of fragments filtered (cf. Hirons and Edwards, 1990). If the responses discussed are reflections of the PBO, then the terrestrial vegetation changes overall are in broad agreement with Björck *et al.* (1997) who suggest that much of Europe was characterised by cool, humid conditions during the event.

Percentage LOI is relatively stable, but decreased (cf. SB-3[a]) throughout the zone. Whilst this may indicate decreased productivity within the basin, as has previously been suggested for a number of Swedish and Icelandic basins (Björck *et al.*, 1997), it could also reflect increased inorganic inwash. It is interesting that *Nuphar lutea* and *Nymphaea alba* increase in representation during SB-3(b), being present at similar levels to SB-2. The causes of these increases are unclear, but they could be related to nutrient flushing, water temperature, or perhaps a reduction in shading due to the loss of *Corylus avellana* trees fringing the basin. Microfossils identified as Type 187B of Van Geel *et al.* (1989) and tentatively identified as algal cysts (data not presented) show a similar abundance pattern to *N. lutea* and *N. alba* and may be responding to similar conditions.

Although the above discussion applies to much of zone SB-3(b), *Corylus avellana* influx begins to increase after 354 cm, suggesting that the conditions inhibiting hazel growth only persisted between 357 cm and 354 cm. The duration of the PBO has been estimated as 100-150 cal years (Björck *et al.*, 1997) and even allowing for extremely low sediment accumulation rates, it is unlikely that the deposits between 357 cm and 354 cm cover this period of time. Whilst this may suggest that conditions preventing the growth of hazel did not persist throughout the PBO, in the absence of firmer dating controls conclusions must remain tentative.

Finally, the contraction in the percentage *Corylus avellana* curve occurs after the absolute data suggest that the expansion of the taxon was complete. This compares with the data from Cess Dell and The Bog at Roos where the contraction seems to have occurred during the initial *Corylus avellana* expansion. Assuming that the declines are in response to the same event this suggests either that the expansion of hazel occurred earlier within the catchment of Sproatley Bog, or that the expansions occurred at broadly similar times, but that ecological conditions favoured a more rapid population increase at Sproatley Bog. The possibility that the apparent differences in expansion rate/time are the result of differences in pollen recruitment characteristics between sites cannot be ruled out, however.

Between *ca* 9510±120 BP (AA-30881) and 9290±70 BP (AA-30882; i.e. throughout SB-3[c]) the pollen data suggest that the vegetation of the catchment returned to similar composition to SB-3(a), with *Corylus avellana* woodland dominant and *Betula*, open ground and damp grassland taxa reduced. The similarity of the two subzones shows clearly in the DCA plot, with the zone averages for the first two axes of the ordination being almost identical (Figure 8.28). Charcoal and percentage LOI levels are also similar and there is no evidence that the environmental conditions discussed above for SB-3(b) had any lasting effects on soil characteristics.

Between *ca* 9290±70 BP (AA-30882) and *ca* 8975±75 BP (AA-30883; i.e. during SB-3[d]) there is evidence for increased levels of vegetational disturbance within the pollen catchment. *Corylus avellana* declines in percentage representation from 75.2 % TLP at 335 cm to 58.8 % at 334 cm, with values fluctuating between *ca* 52 % and 62 % throughout SB-3(d) and minima at 331 cm, 326 cm and 320 cm (Figure 8.14). The influx data seem reliable for this period and show a significant decrease in *Corylus avellana* (see Figure 8.17), with levels approaching those of SB-3(b). This suggests a greater decline in the pollen input of the taxon than immediately evident from the percentage curve. The influx data show minima for the taxon at the slightly different depths (cf. the percentage data) of 334 cm, 327 cm and 318 cm, and it is these depths that are used in the discussion below. The pollen record indicates that the taxon partially recovered after the first two declines, with complete recovery only occurring at the start of SB-4 (*ca* 8975±75 BP; AA-30883).

Poaceae undiff., *Achillea*-type, *Artemisia*-type and *Plantago major/media* are consistently present throughout SB-3(d), and *P. lanceolata*, Lactuceae undiff. and Chenopodiaceae undiff. occur sporadically, suggesting an increase in the level of open, disturbed ground. *Filipendula, Ranunculus acris*-type and *Equisetum* also increase in frequency (and influx; Figure 8.17) perhaps indicating the expansion of damp-ground communities, possibly due to a rise in the local water table. Whilst *Betula* increases in representation (Figure 8.14), the absolute data suggest that this is largely a proportional effect due to decreasing *Corylus avellana* influx (Figures 8.16 and 8.17) and there is no evidence that the genus expanded significantly during SB-3(d). A similar argument can account for the percentage increases in *Salix, Pinus sylvestris* and Pteropsida (monolete) indet. during the subzone (cf. SB-3[c]).

Whilst the AP:NAP ratios (Figure 8.14) suggest that arboreal pollen representation was slightly higher during SB-3(d) than during SB-3(b) or SB-2, percentage LOI levels are significantly lower. Values drop at the opening of the zone from *ca* 70 % to 42.1 % then steadily decline, reaching a minimum of 18.8 % at 318 cm. The presence of considerable levels of clay within the profile between 330 cm and 316 cm indicates that the decline was largely due to increased erosion, rather than a decrease in autocthonous productivity as discussed previously for SB-3(b). It is likely that considerable soil disturbance and erosion occurred within the catchment during SB-3(d). There is little to suggest that significant reworking of older pollen was associated with this erosion (see 8.4.1.2).

Charcoal levels are much increased during the subzone reaching their highest Holocene levels. Although charcoal to pollen ratios are moderate to high throughout SB-3(d), there are three distinct peaks centred upon 333 cm, 326 cm and 318 cm (Figure 8.14), each spanning *ca* 40-60 ^{14}C years (assuming the validity of the radiocarbon dates). There is no evidence that the widths of the peaks are due to the mixing of one fire event across several cm of deposit as the sharpness of the palynological changes suggest that mixing (at least of pollen) within the profile was minimal during SB-3(d). It also seems unlikely that the relatively long durations of the peaks are the result of delayed secondary inwash from one burning event (cf. Millspaugh and Whitlock, 1995), and it seems more probable that they reflect three periods of increased burning.

Whilst the disturbances evident in the vegetational and erosional records could feasibly be the result of natural processes such as windthrow, it is unclear why repeated landscape-scale disturbance events should have occurred within the catchment of Sproatley Bog between *ca* 9290±70 BP (AA-30882) and *ca* 8975±75 BP (AA-30883), but not before or after this period, or in the records from the other study sites. The increased charcoal input is also hard to explain by purely natural mechanisms. The catchment vegetation is likely to have been of relatively low flammability (Rackham, 1980) and there is little palynological evidence to suggest that the vegetation was particularly dry. It seems highly unlikely that natural burning due to lightning strikes would have occurred on a sufficiently frequent basis within the catchment to account for the charcoal record, particularly when burning appears to have been infrequent within the catchments of Cess Dell and The Bog at Roos during this period (Figures 6.15 and 9.14), despite their similar locations, topographies and vegetational compositions. It is also difficult to account for the charcoal peaks by an increase in the reworked component, as percentage LOI is uniformly low.

It is thus possible that the increases in vegetational disturbance, erosion and charcoal input during SB-3(d) reflect Early Mesolithic activity within the site catchment. The three charcoal peaks correspond closely to the declines in *Corylus avellana* influx, with the initial two lagging 1 cm behind the corresponding hazel minima, and the third coinciding exactly with the last hazel minimum. Despite the close association between high charcoal and low hazel influx it is not possible to say with any confidence whether fire was used as a direct clearance agent (Edwards and Ralston, 1984; Tipping, 1996). Although fire may have been utilised as a tool to clear areas of hazel woodland, it is uncertain whether the community would have been particularly flammable (see above). Simmons and Innes (1996a) suggest that whilst fire may have been used to maintain open areas on the North York Moors during the later Mesolithic, the initial clearings were created in some other way. It is possible that the charcoal influx at Sproatley Bog also reflects the use of fire to maintain (but not to create) open areas, supplemented by input from camp fires. The reduction in hazel may reflect clearance for firewood, material resources or to encourage game, with the increase in ruderal pollen probably reflecting the combination of growth in cleared areas and on trampled ground.

The presence of a series of clearly defined *Corylus avellana* minima and charcoal maxima separated by partial woodland regeneration and lower charcoal levels suggests that disturbance activity was not constant through time, with activity most intense between the dates of *ca* 9290-9240 BP, 9180-9130 BP and 9070-9030 BP (assuming the accuracy of the radiocarbon dates). Given the presence of repeated disturbance events, each of *ca* 40-50 ^{14}C years and separated by *ca* 50 ^{14}C years of partial *Corylus avellana* regeneration, it is tempting to suggest that the area close to the basin was occupied, or the catchment vegetation managed, in a cyclical fashion. At the least it is possible that Mesolithic peoples may have modified the vegetation around Sproatley Bog, whether accidentally or deliberately on several occasions between *ca* 9290±70 BP (AA-30882) and *ca* 8975±75 BP (AA-30883).

A number of vegetational changes occur at the transition to SB-4 (*ca* 8975±75 BP; AA-30883). *Quercus* (most probably *Q. robur*; see section 6.5) began to expand locally after *ca* 8965 BP (Figures 8.15, 8.16 and 8.17), with a duration for the expansion calculated as *ca* 370 ^{14}C years. *Ulmus* underwent a marked local expansion at a similar time and the influx and concentration data suggest that full expansion occurred within *ca* 20 ^{14}C years (Figures 8.16 and 8.17). This seems remarkably rapid, particularly when compared with the data from Cess Dell and Gilderson Marr, which suggest that the initial expansions of *Ulmus* took *ca* 400 ^{14}C years. The genus also seems to have expanded considerably later within the catchment of Sproatley Bog than at the other study sites, where expansion began at *ca* 9500 BP. Whilst there is no evidence that this apparent lag is due to a depositional hiatus within SB-3 or at the SB-3(d)/SB-4 transition, this remains a possibility.

The influx data (Figure 8.17) show moderate peaks in *Ulmus* input during SB-3(a) and SB-3(c), and decreased input during SB-3(b) and SB-3(d) and although the influx data should be interpreted cautiously during SB-3 (particularly during SB-3[a] and SB-3[b]), the data appear reliable. It is possible that the peaks are a reflection of increased long-distance transport (as possibly supported by the preservation data; Figure 8.5), or are a function of the overall higher pollen concentrations during SB-3(a) and SB-3(c). Such peaks in influx are not obvious for any other taxa though and it is perhaps more likely that they reflect limited local growth of the genus during SB-3(a) and SB-3(c). It seems that *Ulmus* began to expand locally during SB-3(a), but that expansion was interrupted, perhaps by the hypothesised climatic deterioration during SB-3(b). Expansion may have resumed during SB-3(c), but increased disturbance during SB-3(d) could have again reduced the local population. The low *Ulmus* influx during SB-3(d) may therefore indicate sparse local growth, in which case the rapid rise in influx from *ca* 8965 BP could be due to the expansion (or increased flowering) of an existing local population.

Although *Corylus avellana* representation increases to >70 % TLP after *ca* 8975±75 BP (AA-30883), the influx data suggest that the taxon did not recover to the population levels of SB-3(c), most probably due to competitive exclusion by the expanding *Quercus* and *Ulmus* populations. *Betula, Salix,* Poaceae undiff. and open and disturbed ground herbs (e.g. *Artemisia*-type, *Ranunculus acris*-type and *Plantago major/media*) also decline suggesting a decrease in the area of open ground, most probably due to an increase in canopy density. The decreasing herb component shows clearly in the AP:NAP ratios (Figure 8.14). Percentage LOI rises above 314 cm (Figure 8.14), suggesting that soils rapidly stabilised as woodland cover increased.

The pollen data suggest that mixed *Quercus-Ulmus-Corylus avellana* woodland dominated the site catchment from *ca* 8975±75 BP (AA-30883), with low levels of *Fraxinus excelsior* and *Hedera helix* (Figure 8.10). Although *Pinus sylvestris* pollen occurs in most samples, it is likely that pine was locally scarce or absent throughout SB-4.

(iii) The Late Mesolithic; post *ca* 8600 BP (post *ca* 9580 cal BP)

The Late Mesolithic is covered primarily by the upper part of SB-4, and whilst it is not possible to assign a reliable end-date to the zone due to a combination of poor dating controls and the hypothesised hiatus at *ca* 222 cm (see section 8.4.1.2), the zone clearly ends after *ca* 8090±75 BP (AA-30884) and prior to the local expansion of *Alnus* (see Figure 8.10).

The pollen record suggests that mixed *Quercus-Ulmus-Corylus avellana* woodland continued to form the dominant vegetation type, with the AP:NAP ratios (Figure 8.13) indicating that woodland cover was relatively complete. This is supported by the DCA plot with the mean zone score for the first two axes of the ordination situated amongst the woodland taxa towards the top-left of the plot (Figure 8.28). Whilst AP:NAP ratios decline above 272 cm (from *ca* 8100 BP; Figure 8.13), this is largely due to an increase in Pteropsida (monolete) indet. representation (Figure 8.12). As discussed in section 8.4.1.2 this is likely to be a reflection of the high corrosion levels during the period, the spores being artificially concentrated due to their high corrosion resistance. When spores are removed from the calculation the drop in values is less severe and due primarily to increased Cyperaceae undiff. representation, presumably as a function of hydroseral succession. The declines in *Corylus avellana*-type, *Quercus, Betula* and *Salix* influx above 272 cm probably reflect post-depositional pollen loss due to corrosion, with the taxa showing extremely high corrosion levels during the period (Figure 8.15 and also Figures 8.3, 8.4 and 8.6; preservation data for *Salix* not presented). When the above discussion is considered, there is no palynological evidence for significant disturbance of the woodland mosaic during SB-4 and the extremely low charcoal levels throughout the zone (Figure 8.13) suggest that little burning, whether natural or anthropogenic, occurred within the catchment.

As discussed in section 8.4.1.2, the occurrences of at least three depositional hiatuses between *ca* 222 cm and 164 cm mean that the pollen record within zones SB-5 and SB-6 is incomplete. The pollen curves for the major arboreal taxa are also highly variable (Figures 8.10, 8.15 and 8.18), particularly during SB-5. As such the vegetational records for zones SB-5 and SB-6 will not be discussed further.

(iv) The Historical period; *ca* Pre-1470-1150 BP (*ca* Pre-1360-1030 cal BP)

Whilst dates AA-30887 (1470±40 BP) and AA-30888 (1210±40 BP) suggest that subzone SB-7(b) covers the Mid-Anglo-Saxon (Early Medieval) Period, it is harder to assign a start date to subzone SB-7(a). The basal date of 2610±50 BP (AA-30886) seems to be too old on palynological grounds (see below), and would require that sediment accumulation rates were approximately three times as fast during SB-7(b) than during SB-7(a). Interpolation based upon dates AA-30887 and AA-30888 gives an age of *ca* 1920 BP for the opening of SB-7(a) and dates the first occurrence of *Cannabis*-type pollen (probably *Cannabis sativa,* see below) to *ca* 1850 BP. Whilst the taxon is likely to have been cultivated within England from the Roman Period onwards (Bradshaw *et al.,* 1981), significant levels of cultivation only appear to have occurred during and after the Anglo-Saxon Period (Godwin, 1975). It is possible, therefore, that SB-7(a) covers the Roman and Early Anglo-Saxon periods. It is perhaps more likely that the subzone covers the Early to Mid-Anglo-Saxon Period, a hypothesis which is in greater agreement with the palynological data (discussed below). Due to these uncertainties, interpolated dates prior to 1470 BP are not included.

It is likely that conditions of open-water were re-established during SB-7(a) due to the flooding of a pit formed during peat-cutting or dug specifically for the purposes of retting hemp (*Cannabis sativa*) or flax (*Linum usitatissimum*) fibres (see below). The fluctuations in the major pollen type and percentage LOI curves below 146 cm (Figures 8.19, 8.20 and 8.23, and also the summary diagram in Figure 8.23) may subsequently be due to the mixing with older deposits as the basin consolidated. The record seems sound above this point (i.e. for much of SB-7[a]; see 8.4.1.2) and is discussed in detail below.

The pollen data suggest that the landscape was largely cleared and heavily cultivated during SB-7(a), with non-arboreal pollen accounting for *ca* 30-70 % TLP throughout the subzone (Figure 8.23; see also the DCA plot, Figure 8.28). It is likely that limited populations of *Corylus avellana* and *Quercus* occurred within the catchment, the taxa perhaps growing as areas of scrub, although the *Quercus* influx could equally indicate the growth of isolated individuals. The low levels of *Fraxinus excelsior, Ulmus* and *Betula* pollen along with the occasional grains of *Acer campestre*-type and *Fagus sylvatica* (Figure 8.19) may indicate the sparse local presence of the species, but could also reflect long-distance transport from outside of the study area.

The non-arboreal pollen record is dominated by open and disturbed ground taxa, particularly Poaceae undiff. and Cyperaceae undiff. at *ca* 30-35 % and 15-20 % TLP respectively. It is possible that much of the Cyperaceae undiff. input originated from plants fringing the basin (as supported by the finding of *Carex* seeds within the deposit; Figure 8.26). Taken collectively, the herb data (Figures 8.20 and 8.21) indicate the existence of several landscape elements. The presences of *Astragalus danica*-type, *Centaurea nigra*-type, *Plantago lanceolata, Ranunculus acris*-type and *Rumex acetosa* reflect the occurrence of grassland, at least part of which is likely to have been utilised as meadow and/or pasture. The consistent presence of *Rumex acetosella* may also indicate dry (possibly acidic) grassland, but could reflect growth of the taxon as an arable weed (Hauf, 1983).

There is considerable evidence that mixed arable farming occurred within the catchment. Large Poaceae pollen identified as belonging to the *Hordeum* and *Avena-Triticum* groups of Andersen (1979), the Cereal-type of Küster (1988) and also *Secale cereale*-type is consistently present at <3 % TLP (Figure 8.20 and Table 5.5). Although the data presented in chapter 5 suggest that it is not possible to reliably separate *Hordeum, Avena* or *Triticum* from some wild grasses using the approaches employed in this study, on the basis of pollen record as a whole it seems likely that most of the grains located during SB-7 originate from cultivated taxa. *Linum bienne*-type also occurs sporadically at low levels. Whilst the pollen of *L. bienne* (pale flax) is indistinguishable from that of *L. usitatissimum* (cultivated flax; Moore *et al.*, 1991), seeds of cultivated flax were located within the profile (Figure 8.26) and it is likely that the pollen originated from the taxon. The presence of *Cannabis*-type pollen throughout SB-7(a) at <5 % TLP is also of interest. Analysis of the pore characteristics using the method of Whittington and Gordon (1987) suggests that most (possibly all) of the grains located from six samples within SB-7(a) and SB-7(b) are likely to originate from *Cannabis sativa* (hemp) rather than *Humulus lupulus* (hop; Table 8.5). This is supported by the ecological characteristics of the two species with *Humulus lupulus* occurring most frequently in fen woodland (Rose, 1985), a habitat not suggested by the pollen data. It is also unlikely that hop growing for brewing could account for the levels of pollen influx observed, particularly during SB-7(b). Pollen attributable to *Cannabis sativa* has been found previously in the historical records from a number of sites within the British Isles (e.g. Godwin, 1967a, 1967b, 1975; Hall *et al.*, 1979; Bradshaw *et al.*, 1981; French and Moore, 1986; Edwards and Whittington, 1990; Dumayne and Barber, 1994) and beyond (e.g. Gaillard and Berglund, 1988; Latalowa, 1992). The interpretation of the *Cannabis sativa* curve is discussed in detail below.

Given the evidence for farming discussed above, it is probable that the high frequencies of open, disturbed ground herbs including *Achillea*-type, *Artemisia*-type, Brassicaceae undiff., Caryophyllaceae undiff. and Lactuceae undiff. reflect their growth around field edges on pathways, or as arable weeds. The pollen record as a whole, in particular the association of flax, hemp, rye and other cereals is very similar to the Anglo-Saxon and Norman record from Old Buckenham Mere, Norfolk (Godwin, 1967b, 1975).

It is likely that the area of scrub/woodland steadily decreased during SB-7(a), with arboreal representation declining from *ca* 60 % to 30 % TLP during the zone. The absolute data suggest that this was largely a result of reductions in the local populations (or at least pollen production) of *Quercus* and *Corylus avellana.* The increased landscape openness towards the end of the subzone shows clearly in the AP:NAP ratios (Figure 8.23), with the percentage LOI curve suggesting that erosion increased coincident with this clearance. Charcoal levels are high and fairly stable during SB-7(a) and given the evidence for intense human activity within the catchment it is probable that much of this input reflects anthropogenic burning.

A number of changes occur after *ca* 1470±40 BP (*ca* 600 AD; AA-30887; i.e. during SB-7[b]), particularly within the herb component. Although the AP:NAP ratios and influx data for the main arboreal types (Figures 8.23 and 8.25) suggest that the landscape was of similar openness to the latter part of SB-7(a), *Betula* and *Ulmus* influx both decrease suggesting that the taxa became less frequent (Figure 8.25). The lack of evidence for any significant area of woodland within the catchment compares favourably with the records for the area at the end of the Anglo-Saxon Period (Faull and Stinson, 1986), with any remaining woodland likely to have been carefully managed (cf. Rackham, 1994a, 1994b; Berryman, 1998). There is also evidence for changing land-use within the site catchment. Arable weeds including *Centaurea cyanus, Alchemilla*-type (if from *A. vulgaris*) and perhaps *Plantago major/media* become more frequent, *Secale cereale*-type occurs in all samples, and percentage LOI decreases slightly. This suggests either that the intensity of cultivation increased, or that the location of fields changed. The declining *Plantago lanceolata* influx (Figure 8.25) may indicate a reduction in the area of grassland coincident with the above changes, or that the type of grassland changed. *Cannabis*-type (presumably *Cannabis sativa*) representation also increases to between *ca* 5% and 15 % TLP, peaking at >30 % TLP at 96 and 88 cm and the lower charcoal levels probably indicate a decrease in anthropogenic burning within the catchment.

Several points are of relevance concerning the vegetational record of SB-7. Firstly, the strength of the cultivation signal suggests that the field system is likely to have been located close to the basin, particularly given the relatively poor dispersal ability of the larger cereal pollen grains (Vuorela, 1973). This is interesting as the basin lies close to the approximate location of the East Field of the later historical open field system of Sproatley village (Figure 3.14; based upon OS map). The early origins of the open field system are unclear, but it is likely that it originated prior to the Middle Ages (Thirsk, 1987) and possibly during the Anglo-Saxon Period (Ernle, 1967; Orwin and Orwin, 1967; Hooke, 1998). Although intriguing, the Sproatley Bog data do not allow this possibility to be satisfactorily assessed.

Secondly, the high levels of *Cannabis sativa* pollen, particularly during SB-7(b), raise the possibility that the site may have been used for retting hemp fibres prior to their use in linen or rope manufacture (Gordon, 1980). The presence of *Cannabis sativa* pollen at the high levels of *ca* 15-34 % TLP between 96 cm and 84 cm (*ca* 1385-1465 BP) is difficult to explain unless retting of fibres within the basin is invoked. Values throughout the rest of SB-7 never exceed 11 % TLP though and could equally reflect local growth of the taxon, particularly as it is a relatively high pollen producer (Edwards and Whittington, 1990). In order to further investigate the hypothesis that retting of hemp (and possibly flax) may have occurred within the basin, plant macrofossils and Coleopteran remains were analysed throughout SB-7. Although no *Cannabis sativa* achenes or fibres were located, this does not by itself argue against the site being used as a retting pit due to the small sediment volume used for macrofossil analysis and the observation that seeds were often removed prior to retting for use as a source of oil (Bradshaw *et al.*, 1981). Two flax seeds were, however, found in the sample from 116-112 cm (Figure 8.26) supporting the hypothesis that flax may have been retted within the basin.

The aquatic pollen and seed records (Figures 8.22 and 8.26) suggest that the basin contained a rich flora throughout SB-7, with taxa including *Myriophyllum verticillatum*, *Sparganium emersum*-type, *Menyanthes trifoliata* and Potamogetonaceae undiff. frequent. Input is particularly high during SB-7(b) with *Myriophyllum verticillatum* often exceeding 60 % TLP and *Myriophyllum alterniflorum* increasing to *ca* 4-12 % TLP. The increase in aquatic input at the transition from SB-7(a) to SB-7(b) may be related to changing nutrient status or water depth. The Coleopteran data (Figure 8.27) largely support the aquatic plant record and suggest a clear, well vegetated, probably eutrophic pond (see Table 8.6). Trichoptera (caddis fly) larval cases were also present in most samples, but as none of the individuals could be identified to family level, little more can be said. Although sample sizes are very low and the faunal record is likely to be incomplete, there is nothing to suggest that the water was particularly foul. There is certainly no evidence that conditions within the basin deteriorated as *Cannabis sativa* representation increased during SB-7(b). This is interesting given the observation that hemp retting produces foul, odorous water conditions (Tusser, 1580 quoted in Bradshaw *et al.*, 1981).

When the data are considered as a whole, it is perhaps likely that some retting of *Cannabis sativa* occurred within the site (at the very least between *ca* 1465 BP and 1385 BP), but that the water had time to clear between retting episodes or was flushed periodically with clean water (perhaps intentionally or due to seasonal flooding). Alternatively, retting may have occurred in a nearby pit, with pollen contaminating the cored basin. As the hemp plants were probably grown locally, it is likely that the record is at least in part reflecting local growth of the crop. The increase in *Cannabis sativa* representation during SB-7(b) may be a reflection of an increase in the frequency or volume of retting, or a switch from the use of predominately female to predominately male plants (Edwards and Whittington, 1990).

If the site was used for the retting of hemp and/or flax then it is possible that part of the pollen input may represent contamination by pollen washed off from plants brought into the basin. The sediments may also have been disturbed during the retting process, although there is no clear evidence of this in the pollen data.

(v) Summary

The vegetational record suggests that the landscape surrounding Sproatley Bog was largely open during the Younger Dryas, but predominately wooded during the early Holocene. There is evidence for considerable disturbance of the dryland vegetation along with elevated charcoal levels and soil erosion between *ca* 9290 BP and 8975 BP. Whilst the vegetational disturbance could potentially reflect natural processes such as repeated windthrow, the charcoal record is harder to explain and it seems more likely that the events are reflecting the actions of Mesolithic peoples. There is evidence for at least two depositional hiatuses before open water conditions became re-established, probably during the early-mid Anglo-Saxon period. It is possible that the open water conditions were the result of peat cutting or the digging of a pit for retting hemp and/or flax. The pollen data suggest that the landscape around the site was largely cleared and intensively farmed during the Anglo-Saxon period.

A summary of the development of the landscape around Sproatley Bog is presented in Table 8.8

Chapter 9: The Bog at Roos: results and discussion

9.1 Introduction

This chapter presents the analytical results of the core obtained from The Bog at Roos. A description of the core is given in section 9.2 and the radiocarbon dating programme is assessed in section 9.3. The results of the pollen analyses are introduced in section 9.4, where deteriorated pollen and local pollen assemblage zones are suggested. Finally, the vegetational and wider development of the site catchment is discussed in detail in section 9.5.

9.2 Core description

A detailed description of the core is given in Table 9.1.

The core stratigraphy and palynological results suggest that the profile covers much of the Holocene and part of the Younger Dryas. The core site was not bottomed, but previous investigations by Beckett (1975) show that the basin also contains an apparently complete Younger Dryas and Late-Glacial Interstadial record. The core section between 616 cm and 1 cm was sampled for laboratory analysis.

9.3 Radiocarbon dating

Fourteen AMS radiocarbon dates were obtained for the profile (Appendix 6). The bulk of the dates seem reasonable, although several points can be made. Firstly, it is quite possible that date AA-32289 (9525±90 BP) lies within the 9500-9600 BP radiocarbon plateau (Kromer and Becker, 1993; Stuiver and Reimer, 1993), and the calibrated age range for the date (10870-10690 cal BP) and accumulation rates for the earliest Holocene should subsequently be treated cautiously. Secondly, dates AA-32294 (275-276 cm; 4495±60 BP) and AA-32295 (241-242 cm; 4400±80 BP) overlap significantly at 1 SD (Figure 9.1) and as such are not reliably separable. This implies either that sediment accumulation rates were particularly fast during this section of the core (<3 ^{14}C years/cm) or that one, or both, of the dates is/are unreliable. Excluding date AA-32294 from the calculation of sample ages gives sediment accumulation rates of *ca* 11.6 years/cm between 317 cm and 154 cm and an age of *ca* 3380 BP for the sample at 154 cm, whilst excluding date AA-32295 gives rates of *ca* 2.8 years/cm and an age of *ca* 4160 BP. As sediment accumulation rates for the more securely dated sections of the profile generally vary between *ca* 7 years/cm and 18 years/cm, rates (and interpolated ages) appear more realistic when date AA-32294 is excluded, perhaps suggesting that the date is too young (possibly from rootlet contamination). Whilst the data are far from clear this approach was used and accumulation rates and interpolated dates should subsequently be interpreted with caution between the depths of 317 cm and 154 cm. Finally, there is evidence within the palynological data for a depositional hiatus at *ca* 154 cm and age interpolations and accumulation rate calculations for this section of the core are subsequently felt to be inaccurate. Dating for the section of the profile between 166 cm and 122 cm is discussed in detail in section 9.4.1.2.

A time-depth curve of calibrated and uncalibrated BP dates is presented in Figure 9.1. Sediment accumulation rates were relatively even within the lower gyttja (*ca* 608-379 cm) and upper peat (*ca* 152-49 cm) units.

9.4 Pollen data

The following LDPAZs are numbered from the bottom up and prefixed by the initials RBODET, whilst LPAZs are prefixed by the initials RBO. The initials RBO were assigned to avoid confusion with the earlier investigations of Beckett (1975, 1981) where the initials RB were used. LDPAZs are labelled alphabetically and LPAZs numerically.

9.4.1 Deteriorated pollen analysis

9.4.1.1 Local deteriorated pollen assemblage zones (LDPAZs)

A diagram showing total pollen preservation is presented in Figure 9.2, and a series of diagrams showing the preservation characteristics of the major pollen types are given in Figures 9.3-9.9. Total deterioration percentages are based upon the sum of TLP. Full details of the LDPAZs assigned are presented in Table 9.2, and a DCA plot of the average LDPAZ and deterioration type scores for the first two axes of the ordination is presented in Figure 9.10.

a) RBODET-A: 616-393 cm; *ca* 10,170-7625 BP (*ca* 11,800-8410 cal BP)

Pollen preservation is initially moderate with 17-30 % TLP deteriorated between 616 cm and 610 cm, but it is good throughout the rest of the zone with *ca* 5-10 % deteriorated. Although the preservation characteristics are significantly different below 608 cm, the low number of levels analysed below this depth (i.e. 3) meant that it was not felt appropriate to assign the samples to a different LDPAZ. Below 608 cm, broken grains dominate at 6-12 % TLP, with crumpled and type-1 corroded grains present at >3 % and 4-8 %, respectively. Above this depth broken grains continue to dominate, but at reduced levels of *ca* 3-5 % TLP and crumpled grains occur at <1.5 %. Type-1 corroded grains drop to <1 % at 608 cm before steadily increasing to 3-6 % for much of the zone. Type-2 corroded and amorphous grains are present throughout, generally at <1 %. Indeterminable grains occur sporadically and comprise all deterioration forms.

Percentage LOI is initially low at 15.6 %, but rapidly rises, being stable at *ca* 80-90 % between 604 cm and 572 cm. Levels then fluctuate between *ca* 60 % and *ca* 80 % until 530 cm, with percentage LOI at 72-80 % above this point. The samples come from gyttja with the exceptions of 616 cm and 612 cm which are from clay.

b) RBODET-B; 393-371 cm; *ca* 7625-7215 BP (*ca* 8410-8000 cal BP)

The zone opens with a slight increase in pollen deterioration to between 15 % and 30 % TLP, with preservation becoming good to moderate. Type-1 corrosion is the dominant form of deterioration at 9-20 % and broken grains are present at 4-9 %. Crumpled, amorphous and type-2 corroded grains occur at similar frequencies to RBODET-A and indeterminable grains remain rare.

Percentage LOI is high throughout at *ca* 80-90 %. All of the samples are from gyttja.

c) RBODET-C; 371-306 cm; *ca* 7215-5065 BP (*ca* 8000-5820 cal BP)

Pollen preservation improves with total deterioration generally below 10 % TLP apart from the samples from 308 cm and 312 cm where 18 % and 40 % of grains respectively are deteriorated. The initial improvement in preservation is largely due to a drop in the level of type-1 corrosion to below 2 %, although levels reach 11.5 % and 31.6 % at 308 cm and 312 cm. Broken, type-2 corroded, crumpled, amorphous and indeterminable grains occur in similar abundances to the preceding zone.

Percentage LOI remains high at *ca* 80-100 % and all of the samples are from gyttja, with the exception of 308 cm and 312 cm which are from woody peat.

d) RBODET-D; 306-275 cm; *ca* 5065-4780 BP (*ca* 5820-5530 cal BP)

Pollen preservation becomes slightly poorer, but remains good with 13-17 % TLP deteriorated. This increase is largely due to rises in the proportions of broken and crumpled grains to 12-15 % and 2-3 % respectively. Type-2 corroded grains are absent and type-1 corroded grains are significantly reduced, occurring only sporadically. Amorphous and indeterminable grains are present at similar levels to RBODET-C.

Percentage LOI is high at around 90-100 % and all of the samples are from peat.

e) RBODET-E; 275-251 cm; date range uncertain, but perhaps *ca* 4780-4520 BP (*ca* 5530-5120 cal BP)

Pollen deterioration increases to between 23% and 27 % TLP, with preservation moderate. The bulk of this increase is due to corrosion, with type-1 corrosion present at 3-5 % TLP and type-2 corrosion consistently occurring at <1 %. Levels of broken and crumpled grains also increase slightly to *ca* 15-17 % and 4-6 % respectively. Amorphous grains remain infrequent and indeterminable grains never exceed 1 %.

Percentage LOI is slightly lower (cf. RBODET-D) at *ca* 80-85 % . Samples between 274 cm and 262 cm are from gyttja and those between 260 cm and 252 cm are from peat.

f) RBODET-F; 251-162 cm; date range uncertain, but perhaps *ca* 4520-3480 BP (*ca* 5120-3760 cal BP)

Preservation improves slightly through this zone with 23-27 % TLP deteriorated. Crumpled and type-1 corroded grains are reduced to <3 % and <1 % respectively and type-2 corroded grains only occur occasionally. Broken and amorphous grains are present at similar frequencies to the preceding zone, and indeterminable grains remain infrequent and consist almost entirely of broken grains.

Percentage LOI is high at between 90 % and 100 % and all samples are from peat.

g) RBODET-G; 162-122 cm; dating uncertain, but perhaps *ca* 3480-1980 BP (*ca* 3760-1930 cal BP)

Pollen preservation is poor between 160 cm and 154 cm and again between 140 cm and 124 cm (with *ca* 35-50 % TLP deteriorated), but moderate between 152 cm and 144 cm (*ca* 15-25 % deteriorated). These changes are largely due to variations in the level of corrosion. Type-1 corrosion increases at the opening of the zone, peaking at 15.6 % at 154 cm, before dropping to below 3 % until 144 cm when levels again increase, reaching 25.1 % at the end of the zone. Type-2 corrosion is also initially high, peaking at 28.3 % TLP at 156 cm. Levels then decline steadily until 150 cm, after which type-2 corroded grains only occur sporadically. Crumpled grains increase slightly to between 3 % and 5 % and broken and amorphous grains occur at similar frequencies to RBODET-F. Indeterminable grains never exceed 0.5 % TLP and consist predominately of broken and corroded (undiff.) grains.

Percentage LOI is similar to RBODET-F at around 90-100 % and all samples are from peat.

h) RBODET-H; 122-1 cm; *ca* 1980 BP-present (*ca* 1930 cal BP-present)

Pollen preservation is good to moderate throughout the zone with generally around 15-25 % TLP being deteriorated. Crumpled grains occur initially at 3-5 %, but steadily increase above 20 cm, peaking at 11 % at 8 cm. Type-1 corroded grains occur at <2 % during the lower part of the zone, increasing to 2-6 % above 56 cm, and levels of amorphous and broken grains are also variable. Type-2 corroded grains are infrequent and indeterminable grains never exceed 1.7 % TLP.

Percentage LOI is between 85 % and 100 % for much of the zone, dropping slightly to around 80 % between 12 cm and 4 cm. The samples from 112 cm and 110 cm are from *Sphagnum* peat and all other samples are from amorphous peat.

9.4.1.2 Interpretation

The following section evaluates the main results of the pollen preservation analysis. The discussions centre upon LDPAZs where the preservation data indicate changing taphonomy or that the pollen record may be unreliable or altered in some way. A summary of the preservation analysis is provided in Table 9.3. Specific points, particularly those relating to individual pollen types, will also be drawn upon in section 9.5 to aid the discussion of the vegetational record.

(i) RBODET-A; *ca* 10,170-7625 BP (*ca* 11,800-8410 cal BP)

Whilst pollen preservation is generally good, broken and crumpled grains are relatively more frequent below 608 cm. Percentage LOI is particularly low within this section of the profile and it is possible that the data are reflecting mechanical damage caused during erosional inwash (cf. Birks, 1970). The elevated levels of type-1 corroded grains below 608 cm also indicate the input of pollen that had been previously exposed to oxidising conditions, perhaps signifying inwashing from the litter layer or older deposits. Whilst generally sound it is subsequently possible that the earliest Holocene pollen record contains a reworked (potentially older) component. This is supported by the abundance of Pre-Quaternary microfossils below 608 cm (data not presented).

(ii) RBODET-C; *ca* 7215-5065 BP (*ca* 8000-5820 cal BP)

Preservation is good and the pollen record is apparently sound between *ca* 7215 and 5220 BP (324-316 cm), but the moderate to high levels of type-1 corrosion at 312 cm and 308 cm require discussion. Increases in type-1 corrosion occur in all of the major taxa (Figures 9.3-9.8) and coincide with a stratigraphical change, the samples both from woody peat. It is conceivable that the elevated type-1 corrosion levels reflect the exposure of pollen to oxidising conditions during or after peat formation, most feasibly as a result of drying of the deposit. The high frequencies of Pteropsida (monolete) indet. spores at 308 cm (54.7 % TLP) raise the possibility that the spores may have been artificially concentrated due to loss of more corrosion susceptible taxa, but there is little wider evidence within the pollen spectra to suggest that significant alteration of the record occurred.

(iii) RBODET-G; dating uncertain, but perhaps *ca* 3480-1980 BP (*ca* 3760-1930 cal BP)

Preservation becomes poor during RBODET-G. Both forms of corrosion increase to between 162 cm and 154 cm (Figure 9.2) and the pollen record changes markedly above 154 cm from one indicating a predominately wooded to an almost entirely cleared landscape. The combination of data suggest that a depositional hiatus occurred at 154 cm and it is possible that some post-depositional pollen loss occurred as a result of corrosion between 162 cm and 154 cm. The date of 2660±50 BP (AA-32296) obtained for 153-154 cm is very close to the proposed location of the hiatus, but seems reasonable when compared to dates AA-32300 (2100±60 BP; 131-132 cm) and AA-32297 (1720±50 BP; 101-102 cm). It is likely that the hiatus covered the period from *ca* 3380 BP to *ca* 2660±50 BP (AA-32296), although this should be taken as a tentative estimate only.

Preservation improves between 152 cm and 136 cm, with corrosion particularly low, but worsens again between 136 cm and 124 cm largely due to an increase in type-1 corrosion to 10-25 % TLP. There is no clear evidence for a second depositional hiatus and it is likely that the corrosion is reflecting seasonal drying of the deposit, or a post-depositional lowering of the water table. The high levels of Pteropsida (monolete) indet. spores between 150 cm and 124 cm and the low pollen concentrations (and influx) between 154 cm and 128 cm collectively suggest that some pollen loss may have occurred as a result of this corrosion, the spores being artificially concentrated due to their high corrosion resistance (cf. Pennington, 1965).

The pollen data thus indicate the presence of a significant depositional hiatus, perhaps between *ca* 3840-3380 BP and 2660±50 BP (AA-32296). Low pollen concentrations, high Pteropsida (monolete) indet. representation, and fluctuating corrosion suggest that the record may also be unreliable between *ca* 2660±50 BP (AA-32296) and *ca* 1980 BP. Dating between 162 cm and 122 cm is subsequently difficult.

(iv) General points

The variation in the level of type-1 corrosion between zones RBODET-A, RBODET-B and RBODET-C is interesting given that all samples above 610 cm originate from gyttja and that the changing deterioration is subsequently not associated with an obvious change in the depositional environment. Whilst conclusions must remain tentative, it is possible that the type-1 corrosion curve is reflecting differences in the dominant mode(s) of pollen recruitment (perhaps the ratio between the proportion of aerial deposited and inwashed or refloated pollen [see Figure 4.1]), the degree of reworking/re-suspension from the basin edge, or some other unknown factor.

Frequencies of broken and crumpled grains are consistently higher within the peat units than within the gyttja. The cause of this is unknown, but it is possible that the data are reflecting differences between the two depositional environments in terms of the dominant mode(s) of recruitment, or that the broken and crumpled grains reflect damage incurred by the pollen during peat formation or whilst exposed on the peat surface.

9.4.2 Local pollen assemblage zones (LPAZs)

The following section describes the LPAZs that have been assigned to the pollen data, with full details being given in Table 9.4. All percentages are based upon the sum of TLP. To take into account the evidence of a prolonged depositional hiatus between *ca* 156 cm and 154 cm and to accommodate the large number of samples analysed from the core, the pollen data have been separated into two sections in the diagrams presented. Percentage diagrams showing samples between 616 cm and 154 cm are presented in Figures 9.11-9.14, whilst diagrams for samples between 152 cm and 1 cm are shown in Figures 9.17-9.20. Summary percentage diagrams for the regions 616-396 cm and 394-148 cm are also given in Figures 9.14 and 9.15 and summary concentration and accumulation rate diagrams are presented in Figures 9.15, 9.16, 9.21 and 9.22. A DCA plot of the mean taxon and mean LPAZ scores for the first two axes of the ordination is shown in Figure 9.23.

a) RBO-1: 616-583 cm; *Betula*-Poaceae; *ca* 10,170- 9520 BP (*ca* 11,800-11,000 cal BP)

Betula rapidly expands to dominate the record at 60-75 % TLP, with *Salix* and *Pinus sylvestris* present at 4-11 % and 2-5 % respectively. *Corylus avellana*-type increases above 606 cm, peaking at 32.6 % at 592 cm, before steadily declining to 6.6 % at the end of the zone. *Juniperus communis* is present at <3 % below 606 cm and *Quercus* and *Ulmus* occur at <1 % in many levels. *Fraxinus excelsior, Alnus glutinosa* and *Tilia* occur sporadically. Poaceae undiff. drops from 30 % at 616 cm to 3 % at 584 cm and

Cyperaceae undiff. representation declines from 16.6 % at 616 cm to <2 % above 598 cm. Herbaceous taxa are frequent and include *Artemisia*-type, *Rumex acetosa, R. acetosella, Rosa* and Lactuceae undiff. *Filipendula* peaks at 16.6 % at 612 cm, dropping to <2 % above 598 cm and large Poaceae grains occur in most levels. *Empetrum nigrum* and Ericaceae occur infrequently and aquatics, notably *Nymphaea alba* are well represented. *Equisetum* spores occur in most levels at up to 11 % and Pteropsida (monolete) indet. spores are present at 1.5-6 % TLP.

Percentage LOI rapidly rises from 15 % at 616 cm to 63 % at 606 cm and then exceeds 80 % for the rest of the zone. Spherule to exotic ratios are high throughout and charcoal levels are initially very high, but drop throughout the zone to become moderate by 548 cm. Pollen preservation is fair below 610 cm and good above this depth and the zone is covered by RBODET-A. Total pollen and spore concentrations are initially low, but increase to around 250,000-400,000 grains cm^{-3} above 610 cm. Total influx values are also initially low at about 4000 grains $cm^{-2}yr^{-1}$, increasing to 12,000-30,000 grains $cm^{-2}yr^{-1}$ above 610 cm.

b) RBO-2: 583-379 cm; *Corylus avellana*-type-*Ulmus*-*Quercus*; *ca* 9520-7500 BP (*ca* 11,000-8330 cal BP)

Two subzones are demarcated for this zone.

i) RBO-2(a): 583-549 cm; *ca* 9520-9010 BP (*ca* 11,000-10,190 cal BP)

The subzone opens with a rapid rise in *Corylus avellana* representation to 75-85 % and a decline in *Betula* to 5-8 % TLP. *Ulmus* increases at the opening of the subzone to 2-3 % (rising to 4-8 % above 564 cm) and *Salix* declines to <2 % in many samples. The other arboreal taxa are present at similar levels to RBO-1 with the addition of *Sorbus*-type and *Viburnum* at <2 % and the absence of *Juniperus communis*. Heath representation declines with *Calluna vulgaris* present only sporadically. Herbaceous diversity decreases, but *Artemisia*-type and *Filipendula* remain present in most levels at <2 %. Poaceae undiff. is reduced to generally <2 % and Cyperaceae undiff. is also present at <2 % TLP. The aquatic component is similar to the preceding zone, although

Typha latifolia pollen is absent and *Equisetum* and Pteropsida (monolete) indet. occur throughout at <2 %.

Percentage LOI exceeds 80 % below 572 cm and fluctuates between 60 % and 80 % above this depth. Charcoal levels are low and spherule to exotic ratios are similar to RBO-1. Pollen preservation remains good, the subzone being covered by RBODET-A. Total pollen and spore concentrations increase to about 500,000-1x10^6 grains cm^{-3} and total pollen and spore influx increases to 30,000-80,000 grains cm^2yr^{-1}.

c) RBO-2(b): 549-379 cm; *ca* 9010-7500 BP (*ca* 10,190-8330 cal BP)

The subzone opens with a rise in *Quercus* from 2 % at 548 cm to 18 % at 488 cm. Representation of the genus then drops, reaching 4.2 % at 472 cm, before steadily increasing to >25 % towards the end of the zone. *Ulmus* is present at 4-6 % throughout and *Betula* is initially present at 5-8 %, but increases to 8-13 % above 456 cm. *Corylus avellana*-type representation is between *ca* 65-75 % TLP until 412 cm when levels steadily drop to a low of 49 % at 380 cm. *Alnus glutinosa* initially occurs at <2 %, but increases to 3-6 % above 408 cm. *Pinus sylvestris, Tilia, Salix* and *Hedera helix* are present in most levels at <2 %. The herb record is similar to the preceding zone and heaths are represented by the occasional grain of *Calluna vulgaris*. The aquatic and spore records are also broadly similar to RBO-2(a) with the addition of *Polypodium* and *Pteridium aquilinum* at low frequencies.

Percentage LOI is initially similar to the latter part of the preceding zone, but increases to 72-80 % between 530 cm and 394 cm. Levels exceed 80 % between 392 cm and 380 cm. Spherules are frequent and charcoal remains low. Pollen preservation is generally good, the subzone being covered by RBODET-A and RBODET-B. Total pollen and spore concentrations start high at around 100,000-300,000 grains $cm^{-2}yr^{-1}$, but drop to *ca* 50,000-80,000 grains $cm^{-2}yr^{-1}$ above 508 cm.

d) RBO-3: 379-318.5 cm; *Alnus-Quercus-Tilia*; *ca* 7500-5290 BP (*ca* 8330-6050 cal BP)

The zone opens with a marked rise in *Alnus glutinosa* to ~20 % TLP. *Quercus* is initially present at 20-25 %, drops to 14.6 % at 352 cm and then steadily recovers to 25-30 % above 338 cm. *Corylus avellana*-type also fluctuates. Values drop to below 35 % TLP between 370 cm and 356 cm, peak at 51.3 % at 352 cm and then decline again to 30 % between 340 cm and 318 cm. *Tilia* is present at 3-6 % above 370 cm and *Fraxinus excelsior* occurs at <2 % TLP in most levels. The other major arboreal taxa are present at similar frequencies to RBO-2(b) and the heath, herb, aquatic and spore records are also similar to the preceding zone.

Percentage LOI is high at 80-100 %. Charcoal and spherule levels are similar to RBO-2(b), and pollen preservation is good, the zone being covered by RBODET-B and part of RBODET-C. Total pollen and spore concentrations are similar to RBO-2(b) with the exception of 354-336 cm where they increase to ~750,000-3.5×10^6 grains cm^{-3}. Total influx is generally 10,000-20,000 grains $cm^{-2}yr^{-1}$, but increases to 25,000-90,000 grains $cm^{-2}yr^{-1}$ between 354 cm and 338 cm.

e) RBO-4: 318.5-275 cm; *Alnus*-Quercus; *ca* 5290-4790 BP (*ca* 6050-5530 cal BP)

The zone opens with a drop in *Ulmus* representation to <2 % TLP and *Tilia* also declines to <2 % above 312 cm. *Quercus* is initially present at 20 %, but increases above 300 cm to 30-40 %, and *Betula* occurs at 10-15 % until 296 cm when the genus drops to <4 %. *Corylus avellana*-type is present at around 30-40 % and the other major arboreal taxa occur at similar levels to the preceding zone. Heathland taxa are represented by the occasional grain of *Calluna vulgaris*. Herbaceous diversity increases with Caryophyllaceae undiff., Chenopodiaceae undiff., *Plantago lanceolata* and *Rumex acetosella* at low frequencies. Cyperaceae undiff. generally occurs at <2 %, but peaks at 17.5 % at 280 cm and aquatic representation decreases, with *Nymphaea alba* absent above 317 cm. Pteropsida (monolete) indet. spores occur throughout at <2 % (with the exception of 312 cm and 308 cm where levels reach 7.8 % and 54.7 % TLP, respectively), *Polypodium* and *Pteridium aquilinum* are present in most levels at <2 % and *Sphagnum* occurs at 2-14 % above 308 cm.

Percentage LOI is high at *ca* 90-100 %. Spherule to exotic ratios are initially similar to RBO-3, but spherules become absent above 304 cm and charcoal levels are very low. Pollen preservation is good to moderate and the zone is covered by part of RBODET-C and RBODET-D. Total pollen and spore concentrations are generally lower than during RBO-3 at around 200,000-400,000 grains cm^{-3}, but total influx increases slightly to 15,000-30,000 grains cm^{-2} yr^{-1}.

f) RBO-5: 275-241 cm; *Alnus*-Tilia; *ca* 4790-4390 BP (*ca* 5530-4950 cal BP)

A number of changes occur at the start of RBO-5. *Quercus* representation drops to between 13 % and 18 % and *Betula* increases to 10-15 % TLP. *Tilia* increases to 2-7 % and *Ulmus* is present at <2 % below 252 cm, increasing slightly to 2-3 % above this depth. *Corylus avellana*-type representation is variable, but generally similar to the preceding zone and the other major arboreal taxa occur at similar levels to RBO-4. There is an increase in the contribution from heathland taxa with *Calluna vulgaris* present throughout at up to 18 % TLP, but generally at <5 %, and *Empetrum nigrum* occurs at low levels in most samples. Poaceae undiff. expands to between 7 % and 30 % until 270 cm when frequencies drop to <2 %, and herbaceous diversity increases with *Artemisia*-type, Brassicaceae undiff., Chenopodiaceae undiff., *Rumex acetosa* and *R. acetosella* in many samples. Large Poaceae grains are present in most levels and *Plantago lanceolata* occurs at 1.5-5.5 % below 250 cm. Aquatic representation also increases and Pteropsida (monolete) indet. spores occur throughout at 2-6 %. *Pteridium aquilinum* and *Polypodium* occur at <2 % and *Sphagnum* is variable between 8 % and 243 % TLP.

Percentage LOI decreases slightly to between 80 % and 85 % below 250 cm, and increases to >90 % above this depth. Charcoal levels increase, becoming moderate and spherule levels are variable. Pollen preservation is moderate (the zone is covered by RBODET-E and part of RBODET-F). Total pollen and spore concentrations and influx are both similar to RBO-4.

g) RBO-6: 241-153 cm; *Quercus-Corylus avellana*-type-*Betula*; *ca* 4390-3380 BP (*ca* 4950-4320 cal BP)

Quercus recovers to 20-30 % for much of the zone, but steadily drops from 19 % to 14 % after 164 cm, and *Ulmus* is present at 2-4 % below 206 cm and <2 % above this depth. *Betula* initially occurs at 4-6 %, increasing to 15-25 % above 216 cm. *Calluna vulgaris* frequencies are variable at 2-8 % and *Empetrum nigrum* is present at 1-2 % TLP above 180 cm. There is a slight decrease in herb representation, and *Plantago lanceolata* declines to <2 % in most samples. Poaceae undiff. levels are generally <2 %, but increase to 5-15 % above 176 cm and large Poaceae grains are infrequent. Aquatic diversity is reduced with only *Sparganium emersum*-type present and the spore record is similar to RBO-5 with the exception of *Sphagnum,* which increases to 100-417 % TLP for the bulk of the zone (but steadily declines above 196 cm).

Percentage LOI is high at 90-100 %. Charcoal levels are generally low, but become moderate above 160 cm and spherules are largely absent. Total pollen and spore concentrations and influx are similar to RBO-5 and pollen preservation is fair to poor, the zone being covered by parts of RBODET-F and RBODET-G.

h) RBO-7: 153-1 cm; Poaceae-Cyperaceae-*Plantago lanceolata*; *ca* 2660 BP-present (*ca* 2800 cal BP-present)

Four subzones are delimited for this zone:

i) RBO-7(a): 153-102 cm; *ca* 2660 BP-1725 BP (*ca* 2800-1630 cal BP)

Arboreal input is much reduced with non-woody taxa dominating the record. *Quercus* frequencies drop to 2-10 % and *Corylus avellana*-type occurs at *ca* 2-6 % TLP. *Betula* and *Ulmus* are present at throughout at <2 % and *Pinus sylvestris, Fraxinus, Tilia* and *Salix* occur sporadically. *Calluna vulgaris* peaks at between 20 % and 30 % above 112 cm, and *Empetrum nigrum* occurs at 3-48 % above 132 cm. Poaceae undiff. representation is variable, but generally at around 40-60 % and Cyperaceae values increase to 3-13 %. Herbaceous diversity is much increased and includes *Achillea*-type, Brassicaceae undiff. and *Cirsium*-type at <2 % in most levels. *Plantago lanceolata* increases to 4-8 % TLP and *Rumex acetosa* occurs at 10-30 % below 132 cm, declining to 2-7 % for the rest of the zone. Aquatic diversity also increases and includes *Sparganium emersum*-type, which peaks at 114 % TLP at 152 cm. Pteropsida (monolete) indet. spores occur at about 60-180 % TLP until 124 cm when levels steadily drop, reaching 9.4 % at 104 cm. *Polypodium* spores are absent and *Osmunda vulgaris* is present in many levels at <8 %.

Percentage LOI exceeds 90 % throughout the subzone. Spherules to exotic levels are initially low, but increase slightly above 112 cm and charcoal levels are high. Pollen preservation varies between moderate and poor and the zone is covered by RBODET-G and RBODET-H. Total pollen and spore concentrations and influx rates are low at around 30,000-90,000 grains cm^{-3} and 1000-9000 grains cm^{-2}yr^{-1} respectively.

ii) RBO-7(b): 102-86 cm; *ca* 1725-1520 BP (*ca* 1630-1420 cal BP)

A number of changes occur within the non-woody taxa during this subzone. *Hypericum perforatum*-type increases to 5-15 % TLP, *Lotus* occurs at 12-29 % between 94 cm and 98 cm, and *Astragalus danicus*-type and *Rhinanthus* are both present at 10-20 %. Herb diversity and representation is otherwise similar to RBO-7(a), although *Plantago lanceolata* is reduced to <4 %. Poaceae undiff. also declines to between 4 % and 21 % and Cyperaceae undiff. falls to below 2 % (except at 100 cm where the family reaches 19 %). Arboreal representation is similar to RBO-7(a), although *Quercus* is reduced to below 2% TLP and *Acer campestre*-type occurs at one level. *Calluna vulgaris* and *Empetrum nigrum* are present at <10 % throughout and the aquatic record is similar to the preceding subzone. Pteropsida (monolete) indet. spores generally occur at 5-9 %, *Osmunda regalis* frequencies vary between 1 % and 10 % and *Pteridium aquilinum* and *Sphagnum* are present at <2 % in most levels.

Percentage LOI is high at >85 %. Charcoal levels decline to become low to moderate and spherule to exotic ratios increase. The subzone is covered by RBODET-H and pollen preservation is moderate. Total pollen and spore concentrations and influx are similar to RBO-7(a) with the exception of 98 cm and 94 cm where levels increase to between 300,000 and 900,000 grains cm^{-3} and 23,000-71,000 grains $cm^{-2}yr^{-1}$ respectively.

iii) RBO-7(c): 86-14 cm; *ca* 1520-190 BP (*ca* 1420-180 cal BP)

Betula and *Quercus* both increase slightly to 2-5 % TLP and *Fagus sylvatica* is present at low levels in several samples. The other arboreal taxa occur at similar levels to RBO-7(b), and *Calluna vulgaris* and *Empetrum nigrum* occur at 1-9 % TLP, but become scarce above 48 cm. Herbaceous diversity and representation is broadly similar to RBO-7(a), Poaceae undiff. representation recovers to >40 % in many levels and Cyperaceae undiff. pollen increases to around 25-70 %. Large Poaceae grains are also present at 0.5-3 % TLP. Aquatic diversity is high and *Sparganium emersum*-type occurs at 5-20 % throughout. Spores are also frequent with *Osmunda regalis* peaking at 120 % TLP at 78 cm and 80 cm, declining to <10 % above 64 cm. Pteropsida (monolete) indet. spores occur at variable levels, but generally <5 % TLP and *Pteridium aquilinum* occurs at <2 %. *Sphagnum* is initially <3 %, but increases above 36 cm peaking at 779 % TLP at 24 cm.

Percentage LOI is between 85 % and 100 %. Charcoal values are generally moderate, but become very high between 80 cm and 68 cm and spherules are absent above 58 cm. Pollen preservation is moderate (the zone is covered by RBODET-H) and total pollen and spore concentrations and influx are similar to the preceding zone.

iv) RBO-7(d): 14-1 cm; uncertain, perhaps *ca* 190 BP-present (*ca* 180 cal BP-present)

Betula increases to about 5-10 %, *Quercus* and *Corylus avellana*-type decline to <1 % and *Salix* increases to >4 % at 4 cm and 1 cm. *Pinus sylvestris* peaks at 7 % at 12 cm, but is otherwise <3 % and the other arboreal taxa are present at similar frequencies to RBO-7(c). Poaceae undiff. declines from 65 % to 12 % and Cyperaceae undiff. and *Plantago lanceolata* are also reduced at <5 % and <2 % respectively. *Urtica* increases markedly in the top two samples, peaking at 72.7 % at 1 cm. Pollen from heaths is absent and aquatics are less frequent. Spores also decline in importance, with

Polypodium and *Osmunda* absent, *Pteridium aquilinum* infrequent and Pteropsida (monolete) indet. declining from 7% at 12 cm to <1 % at 1 cm.

Percentage LOI is reduced to around 80 % between 12 cm and 4 cm, but reaches 89 % at 1 cm. Spherules are absent, and charcoal levels and pollen preservation are similar to the preceding subzone. Total pollen and spore concentrations increase to about 400,000-1.15×10^6 grains cm^{-3} and total influx also increases to 20,000-40,000 grains $cm^{-2}yr^{-1}$.

9.5 Vegetational history

(i) The Early Mesolithic; *ca* 10,170-8600 BP (*ca* 11,800-9580 cal BP)

The stratigraphical change from clay to gyttja (Figures 9.14 and 9.16) shortly prior to 10,000±120 BP (AA-32288; perhaps *ca* 10,170 BP) is likely to mark the onset of Holocene deposition, with the rapid rise in the percentage LOI curve indicating that the landscape quickly stabilised after this transition. A date of 10,120±180 BP (Birm-405) has previously been obtained by Beckett (1975, 1981) from a similar stratigraphical context within the basin. There is no palynological evidence for a depositional hiatus at the Late-Glacial/Holocene boundary and the site apparently contains a complete Early Holocene record.

Betula representation and influx rapidly increase above *ca* 10,050 BP (Figures 9.11 and 9.18) and the genus dominates the record for much of RBO-1 (between *ca* 10,050 BP and 9520 BP). Although sedimentation rates are likely to have been highly variable during the earliest Holocene and the accumulation rate data are felt to be unreliable (see 9.3), a duration for the expansion of the genus has been tentatively calculated as *ca* 170 ^{14}C years (calculated following the method of Bennett, 1983a). The size-frequency data (Figure 9.26) show no discernible *B. nana* input, although Beckett (1975) suggests that dwarf birch may have formed a limited part of the community during the earliest Holocene. It appears that birch woodland dominated the catchment vegetation prior to *ca* 9520 BP, with the relatively high *Salix* influx suggesting that the genus was also frequent. *Juniperus communis* occurred at low levels and it is probable that *Pinus* *sylvestris* was scarce or absent from the area (see section 6.5 for more complete discussions). The wide diversity of open ground herbs (e.g. *Artemisia*-type, Chenopodiaceae undiff. and *Rumex acetosa*), high Poaceae undiff. representation and low AP:NAP ratios (Figure 9.14) suggest that the canopy was relatively open, or that woodland cover was incomplete. The presence of *Filipendula* and *Ranunculus acris*-type pollen indicates the existence of areas of damp grassland and the low levels of *Calluna vulgaris* and *Empetrum nigrum* suggest that limited heath communities also occurred within the catchment. Large Poaceae pollen occurs throughout RBO-1 and presumably originates from wild grasses (perhaps *Glyceria* or *Elymus*; see section 5.3.2).

Corylus avellana-type representation and influx increase between 604 cm and 592 cm. As previously discussed it seems safe to assume that most (if not all) of this input originated from *Corylus avellana* rather than *Myrica gale* and it will be treated as such throughout the following discussions. Although an interpolated age span for this expansion can be calculated as *ca* 9930-9690 BP, it is likely that this estimate is highly inaccurate. The influx data subsequently need to be interpreted carefully, but appear to be reliable given that the changes in influx for the dominant taxa are similar to those observed in the percentage record. Whilst the data suggest that *Corylus avellana* was locally present and expanding between 604 cm and 592 cm, influx steadily declines above 590 cm, reaching a minimum at 584 cm (Figure 9.18). A similar contraction is seen within the *Corylus avellana*-type curve at Cess Dell and Sproatley Bog and it is possible that it reflects a period of climatic deterioration, most probably the Pre-Boreal Oscillation (*sensu* Björck *et al.*, 1997), as discussed in detail in sections 6.5 and 8.5. It is interesting that the decline in representation occurs at an apparently slower rate than at Sproatley Bog (see Figure 8.14).

Several other vegetational changes occur coincident with the initial expansion of *Corylus avellana*. The low levels of *Viburnum* (probably *V. opulus*) and *Sorbus*-type indicate an increase in arboreal diversity, the taxa becoming present as minor components of the vegetational mosaic, and the increased Pteropsida (monolete) indet. influx suggests that ferns became more frequent within the understorey. There also appears to have been a decline in the level of open or disturbed ground, with Poaceae undiff., *Artemisia*-type, *Plantago major/media* and *Rumex acetosa* becoming less frequent (Figures 9.12 and 9.13). *Juniperus communis* also disappears from the record, presumably reflecting competitive exclusion of juniper by the expanding *Corylus avellana* population.

Charcoal levels are initially very high, but decline throughout RBO-1 as percentage LOI increases. As argued for the other study sites, it is likely that much of the charcoal input during the earliest Holocene was the result of erosional inwash, although limited burning of the open *Betula*-woodland may also have occurred.

From *ca* 9525±90 BP (AA-32289) *Corylus avellana* representation and influx rapidly increase and the taxon dominates the pollen record during RBO-2(a). It is quite possible that the sustained expansion of hazel occurred entirely within the 9500-9600 BP radiocarbon plateau as previously discussed (sections 6.5 and 8.5). This hinders calculation of the duration of the expansion, but a tentative estimate of *ca* 180 ^{14}C years is proposed. Increasing accumulation rates suggest that *Ulmus* became locally present at a similar time, with the genus expanding between *ca* 9500 BP and 9020 BP and the expansion duration tentatively estimated as *ca* 480 ^{14}C years. It is likely that the genus was locally present on the more freely-draining slopes within the catchment throughout RBO-2(a).

It appears that the expansions of *Corylus avellana* and *Ulmus* reduced the local populations of *Betula* and possibly *Salix*, most probably due to competitive exclusion, with a mixed *Corylus-Ulmus* woodland dominating the catchment between *ca* 9525±90 BP (AA-32289) and *ca* 9010±85 BP (AA-32290). Herbaceous diversity and Poaceae undiff. influx (Figures 9.12, 9.13 and 9.18) both drop during RBO-2(a) suggesting that canopy density increased coincident with this change in woodland composition. This is supported by the increased AP:NAP ratios and the position of the mean subzone score amongst the woodland taxa towards the left of the DCA plot (Figure 9.25). Charcoal levels decline with the expansions of *Corylus avellana* and *Ulmus*, probably due to a combination of decreasing erosional inwash, decreased flammability of the vegetation (cf. Rackham, 1980) and greater filtration of fragments by the increasing canopy density (Hirons and Edwards, 1990).

It is interesting that minor peaks of Quercus and Alnus glutinosa occur at the start of RBO-2(a), with occasional grains of Tilia and Fraxinus excelsior also present (Figures 9.15 and 9.18). A similar, but more marked, pattern was seen at Cess Dell (cf. section 6.5) and it is possible that the occurrences of pollen from the above taxa significantly prior to their hypothesised local expansions may reflect a period of marked long-distance transport.

From *ca* 9010±85 BP (AA-32290) the pollen data indicate that *Quercus* (probably *Q. robur*, see 6.5) began to expand locally. The influx data suggest that expansion was complete within *ca* 70 ^{14}C years (Figure 9.18), which seems remarkably rapid, particularly when compared to the durations of *ca* 370-525 ^{14}C years calculated for a similar event at the other study sites. Influx for the genus is highly variable during RBO-2(b) and it may be that this prohibits accurate calculation of the longevity of the expansion using this approach. On the basis of the concentration and percentage data it appears that *Quercus* was expanding locally until *ca* 8650 BP, suggesting an expansion duration of *ca* 360 ^{14}C years which seems more realistic. Total pollen accumulation rates decrease during RBO-2(b), making it difficult to assess which taxa were reduced as a result of the expansion of *Quercus*, but it appears that *Betula, Corylus avellana* and perhaps *Ulmus* declined due to competitive exclusion.

It is likely that mixed *Quercus-Corylus-Ulmus* woodland dominated the catchment of The Bog at Roos between *ca* 9010±85 BP (AA-32290) and 8600 BP, and there is little to suggest that the canopy was significantly disturbed during this period. The trend of decreasing grass and herb contribution continues (as shown by the increasing AP:NAP ratios, Figure 9.14), with Poaceae undiff. at <2 % TLP throughout. Pollen from *Artemisia*-type, *Filipendula* and Chenopodiaceae undiff. still occurs sporadically, however, and *Rosa*-type is present in most samples. Taken as a whole the pollen data suggest that woodland cover and/or canopy density continued to increase during RBO-2(b).

(ii) The Late Mesolithic; *ca* 8600-5500 BP (*ca* 9580-6310 cal BP)

The pollen data suggest that mixed *Quercus-Corylus-Ulmus* woodland continued to dominate the catchment vegetation until *ca* 7525±65 BP (AA-32292), with *Hedera helix* and *Frangula alnus* rarer components. Charcoal levels remain low and there is nothing to indicate that any anthropogenic disturbance (visible at the spatial scale of this study; see section 3.3) occurred during this period.

A number of changes occur during RBO-3 (between *ca* 7525±65 BP [AA-32292] and *ca* 5290±90 BP [AA-32293]), the most obvious of which is the increase in *Alnus glutinosa* representation (Figure 9.16). The influx data suggest that the taxon was expanding between 378 cm and 366 cm (*ca* 7470 and *ca* 7035 BP; Figure 9.18), a duration of *ca* 435 ^{14}C years. Whilst unclear, the influx data suggest that *Alnus glutinosa* may have been locally present at low levels significantly prior to this sustained expansion (perhaps from *ca* 8110 BP; cf. Brown, 1988), although this could equally reflect long-distance transport of pollen from outside the catchment. *Tilia* may have become locally present at low levels at a similar time, with marked expansion of the genus occurring between *ca* 372 and 346 cm (*ca* 7250 and *ca* 6310 BP). This produces an expansion duration of *ca* 940 ^{14}C years, which seems rather long when compared with the duration of similar events at Cess Dell and Gilderson Marr (*ca* 360 and 295 ^{14}C years respectively).

The drop in total accumulation rates at the opening of RBO-3 makes it difficult to ascertain which species were affected by the expansions of *Tilia* and *Alnus glutinosa*, but it seems likely that the local populations of *Betula* and possibly *Salix* and *Ulmus* were reduced. *Corylus avellana* influx also drops as the two taxa expand, but recovers between 354 and 336 cm (perhaps between *ca* 6600 BP and 5940 BP), before declining again towards the end of the zone. It is possible that the initial decline was due to competitive exclusion, but that a reduction in the *Quercus* population allowed hazel to re-expand before it declined once again as the *Quercus* population recovered, however this is not clear from the influx data (Figure 9.18). An alternative possibility is that the decline in *Corylus* may have been a response to a climatic deterioration (most likely the proposed cooling event of Alley *et al.*, 1993), as previously discussed for Cess Dell and Gilderson Marr (sections 6.5 and 7.5). The decline in *Corylus avellana* input apparently occurred between *ca* 7180 and 6670 BP, which is significantly different from the central date of *ca* 7500 BP suggested for the cooling event (Alley *et al.*, 1993; Barber *et al.*, 1999; Hu *et al.*, 1999), however. Environmental conditions during the alder rise are discussed in further detail in section 10.2.4.

(iii) The Neolithic; *ca* 5500-3700 BP (*ca* 6310-4060 cal BP)

The pollen record suggests that mixed *Quercus-Alnus-Tilia-Ulmus* woodland dominated the catchment of The Bog at Roos between *ca* 5500 and *ca* 5290±90 BP (AA-32293), with *Corylus avellana* as a frequent, but reduced (cf. RBO-2[b]) component and *Betula* occurring as a gap-phase taxon. It is possible that *Alnus glutinosa* was present on the elevated land that surrounds much of the basin, but more frequent in the lower lying Roos Valley that encircles this higher ground and abuts the southern end of the site (Figure 3.5), where drainage may have been impeded during this period (Dinnin and Lillie, 1995a).

Several changes occur within the woodland mosaic during RBO-4. *Ulmus* declines to <2 % TLP above 318 cm (from *ca* 5290±90 BP; AA-32293), with the influx data suggesting that the genus was scarce or absent from the catchment throughout the zone. Assigning an end date to the zone is hampered by poor dating controls, but excluding date AA-32294 from the calculation of interpolated ages suggests an age of *ca* 4790 BP. The first elm decline is dated as *ca* 5100 BP across much of the British Isles (Hirons and Edwards, 1986; Edwards, 1998), raising the possibility that the date of 5290±90 BP (AA-32293) may be artificially old. The date is comparable with other dates for the event within Yorkshire though (see section 7.5) and falls within the age range of 5300-5100 BP suggested by Smith and Pilcher (1973). There is no evidence that *Ulmus* ever recovered within the catchment of The Bog at Roos, with influx uniformly low throughout the rest of the record. This contrasts with many pollen profiles from southeast England (Scaife, 1988) and Ireland (Hirons and Edwards, 1986; Scaife, 1988) where *Ulmus* appears to recover (at least partially) following the initial decline.

Tilia also declines in representation during RBO-4, with the influx data suggesting that the genus was locally sparse or absent for much of the zone, but recovered above 284 cm (*ca* 4895 BP; Figure 9.18). This is interesting given that pollen input from the genus decreased prior to the first *Ulmus* decline at Gilderson Marr and increased immediately after the event.

It is possible that humans may have played a role in the declines of *Tilia* and *Ulmus*, or at the least made use of the gaps created by tree-fall (cf. Brown, 1997). Scanning of all levels within the zone for large Poaceae pollen located a grain belonging to the *Hordeum*-group of Andersen (1979) at 320 cm (immediately prior to the *Ulmus* decline [*ca* 5360 BP]) and another referable to the *Avena-Triticum*-group at 317 cm (*ca* 5280 BP; Table 9.5). A second *Avena-Triticum* group grain was also located at 317 cm during routine counting. This raises the possibility that arable agriculture may have been practised within the catchment and that areas of *Tilia* and perhaps *Ulmus* woodland were cleared for this purpose. There is a lack of evidence for wider disturbance of the vegetation, however, with only occasional grains of open ground taxa (e.g. *Plantago lanceolata* and *Rumex acetosella*) found. These could easily reflect the expansion of the herb community into areas previously occupied by *Ulmus* or *Tilia* as part of a natural regeneration assemblage. The apparent expansion of *Quercus* and decline in *Betula* above 296 cm (perhaps *ca* 5035 BP; see Figures 9.16 and 9.18), suggests that disturbance within the areas occupied by these taxa at least may even have decreased. Given that *Tilia* and *Ulmus* seem to have almost completely declined within the catchment, the weakness of the open ground signal is perhaps surprising and may suggest that the available ground was quickly re-colonised. It is also unclear why *Tilia* influx should decline during RBO-4, yet increase again during RBO-5 when relatively intense agricultural activity is proposed (see below). The lack of a clear disturbance signal suggests that any cleared or cultivated areas must have been small-scale or located relatively distant from the basin (see chapter 3 and Edwards, 1979). Whilst this cannot be ruled out it is perhaps more likely that the large Poaceae pollen and reductions in lime and elm had predominately natural origins (see also chapter 5). The declining *Tilia* influx may reflect a locational shift, the poorly dispersed pollen failing to reach the basin (Brown, 1988; Waller, 1994), or a population reduction with the genus declining on the lower-lying land due to a rising water-table in the Roos Valley (cf. Dinnin and Lillie, 1995a). The possible causes of the *Ulmus* decline have been discussed in detail by a number of authors (e.g. Iversen, 1941; Hirons and Edwards, 1986; Girling, 1988;

Scaife, 1988) and will not be discussed further here, but it seems likely that the decline is the reflection of a number of superimposed ecological changes (Hirons and Edwards, 1986). Although charcoal input was already low during RBO-3, levels decrease further during RBO-4. A similar drop has been noted in post-elm decline deposits by a number of other authors (e.g. Bennett *et al.*, 1990; Edwards and MacDonald, 1991; Edwards, 1998) and is discussed further in section 10.3.2.

Vegetational disturbance appears to have increased during RBO-5 (perhaps between *ca* 4790 BP and 4390 BP) with *Quercus* and *Corylus avellana* input reduced (Figures 9.16 and 9.18). Whilst it is possible that the declines may in part be due to competitive exclusion by the expanding *Tilia* population (Figure 9.16), open ground taxa become more frequent and AP:NAP ratios drop (Figure 9.14), suggesting a decline in woodland cover. The presences of *Plantago lanceolata, Rhinanthus, Rumex acetosa* and an isolated grain of *Centaurea nigra*-type collectively indicate an expansion of grassland, whilst other taxa including *Achillea*-type, Brassicaceae undiff., Lactuceae undiff. and *Plantago major/media* signify an increase in the area of disturbed ground within the catchment (Figures 9.12 and 9.13). *Pteridium aquilinum* spores also occur in most samples and could indicate the presence of the taxon within the heath community or the woodland understorey (Grime *et al.*, 1988; Fitter *et al.*, 1995). The increased *Betula* influx may indicate enhanced flowering due to a reduction in canopy density or fragmentation of the woodland cover, but could equally reflect the expansion of the genus as part of a damp woodland flora.

Open-water conditions became re-established within the basin at the start of RBO-5 suggesting that a rise in the local water-table occurred coincident with the above changes. There is also evidence within the palynological data for the expansion of the damp ground and wetland communities, with taxa such as *Ranunculus acris*-type, *Saxifraga stellaris*-type, Potamogetonaceae undiff. and *Sparganium emersum*-type present at low levels. It is possible that the above changes were the result of increased runoff caused by the changing disturbance regime (cf. Moore, 1975; 1988; Innes and Simmons, 1988). This is potentially supported by the pollen preservation data with the increased levels of type-1 corrosion (Figure 9.2) possibly indicating increased inwashing of corroded pollen from the litter layer. It should be noted that other processes including a climatically-induced shift in the water table could also have caused the changes in wetland vegetation discussed above. The occasional grains of *Ilex aquifolium* may reflect inwashing from the litter layer (Pennington, 1979), its presence within the woodland understorey or as part of a 'regeneration assemblage' (cf. Innes and Simmons, 1988).

As previously discussed in the context of Gilderson Marr (section 7.5), it is difficult to produce an ecologically sensible argument that can account for the apparent longevity of the vegetational disturbance observed during RBO-5 (perhaps *ca* 400 ^{14}C years), even allowing for the likelihood that the pollen record is reflecting the combination of a series of discrete disturbance events. Percentage LOI is also reduced, perhaps indicating that erosion increased within the catchment, although the drop in LOI could simply be related to changing sediment properties at the transition from peat to gyttja. Charcoal levels significantly increase during RBO-5 (cf. RBO-4; Figure 9.16), becoming consistently high for much of the zone. Whilst the rise in *Calluna vulgaris* influx suggests that the area of fire-susceptible vegetation within the catchment may have increased during the zone, it seems unlikely that natural ignition would have occurred within the heath community on a frequent enough basis to account for the sustained charcoal influx. Charcoal levels are also low during much of RBO-6 despite the pollen data indicating that heath communities persisted within the catchment. Although part of the increase may be due to a reduction in the number of fragments filtered as a result of canopy opening, it is unlikely that this could account entirely for the record.

It is possible, therefore, that the charcoal and pollen records are reflecting a period of sustained anthropogenic activity within the catchment, between *ca* 4790 BP and 4520 BP. The consistent presence of large Poaceae pollen between 274 and 252 cm (*ca* 4780 BP and 4520 BP; Table 5.6) including grains identified as both the *Avena-Triticum* group of Andersen (1979) and the Cerealia-type of Küster (1988), also raises the possibility that arable crops may have been cultivated close to the site. Given the topography of the area surrounding the basin and the likelihood that drainage would have been impeded on the low-lying landscape of the Roos Valley, it seems likely that the slopes surrounding much of the basin would have provided the most suitable areas for cultivation. On the basis of data presented in chapter 5, a natural origin for the large

Poaceae pollen cannot be ruled out though, the record perhaps reflecting the presence of grasses as part of the wetland flora. It is also impossible to say with certainty whether the increased disturbance and/or burning favoured the spread of the heathland community, or whether another factor was responsible, but the possibility that the hypothesised land-use favoured the expansion of the community remains.

If the record is reflecting a period of woodland clearance and arable cultivation, it would imply a probable Early- to Late-Neolithic presence within the catchment. Whilst by no means conclusive, the archaeological record provides some support for the above hypothesis with a relatively large (95 pieces) mixed-period flint scatter having been found approximately 200 m west of the basin (Head *et al.,* 1995b; Figure 3.5). The authors suggest that much of the material dates to the Early Neolithic, indicating that Neolithic peoples were present within the area during the approximate time period covered by RBO-5.

Although dating remains difficult within RBO-6, it is likely that the zone includes the rest of the Neolithic Period. Between 240 cm and 184 cm (perhaps *ca* 4380-3730 BP) the pollen data suggest that the intensity or frequency of disturbance declined within the catchment, with Poaceae undiff., *Pteridium aquilinum* and open ground taxa much reduced. Pollen from *Artemisia*-type, Chenopodiaceae undiff. and *Plantago lanceolata* remains present at low levels, however, indicating that areas of open ground still occurred within the catchment (as also shown by the AP:NAP ratios). This is supported by the arboreal pollen record, with *Alnus glutinosa* reduced (cf. RBO-5) and the influx of *Quercus* and *Corylus avellana* not increasing significantly (although the percentage representations of the taxa recover to levels similar to those of RBO-4). The increase in *Ulmus* representation during the lower part of RBO-5 is largely a proportional effect due to the declining input from other taxa, with the influx data suggesting that the genus did not expand significantly. Charcoal input is low, although levels increase slightly above 216 cm (perhaps *ca* 4100 BP), suggesting that limited burning may have occurred within the catchment.

Collectively, the data suggest that although disturbance levels declined during RBO-6 the canopy remained relatively incomplete and it is possible that open areas persisted.

This does not necessarily imply that human activity (as proposed for RBO-5) continued within the area, as natural processes such as windthrow and post-clearance grazing (cf. Buckland and Edwards, 1984) could produce a similar palynological signal. If humans were present within the catchment, then any disturbance activity must have been of a lower intensity or scale, or located a greater distance from the basin than during RBO-5.

(iv) The Bronze and Iron Ages; *ca* 3700-1930 BP (*ca* 4060-1890 cal BP)

It is possible that the upper part of RBO-6 may cover the Early Bronze Age, perhaps between *ca* 3700 BP and 3380 BP. The presence of an inferred depositional hiatus at *ca* 154 cm, along with the poor pollen preservation between 162 cm and 154 cm, underscore the caution that should accompany interpretation of this part of the profile.

A number of changes occur within the dryland vegetation coeval with the proposed start of the Bronze Age (above 176 cm). *Quercus* and *Corylus* decline in representation, although the influx data are less clear, and *Betula* input increases. In combination with the high diversity of open ground taxa (e.g. Brassicaceae undiff., Caryophyllaceae undiff., *Cirsium*-type and Lactuceae undiff.) and Poaceae undiff. influx, the data suggest that elevated levels of disturbance occurred within the woodland mosaic. An expansion of the grassland and heath communities is also suggested by the increased *Plantago lanceolata, Pteridium aquilinum* and *Empetrum nigrum* influx (data not presented) and the presence of *Ranunculus acris*-type, *Lotus* and *Rumex acetosa.* Charcoal fragments become more frequent, and it is likely that the intensity or frequency of burning within the catchment increased (although some of the input may be due to decreased filtering of particles by the declining canopy density [cf. Hirons and Edwards, 1990]).

Conclusions must remain tentative given the low number of samples between 180 cm and 154 cm, but it is possible that the change in the disturbance regime reflects the activity of humans, with the large Poaceae grains present during the period perhaps indicating arable cultivation. Several flint scatters dating to the Bronze Age have been found within about 500 m of the basin, suggesting a human presence within the area at some stage during the Bronze Age (Head *et al.*, 1995b; Figure 3.5).

It is likely that the later Bronze Age record is missing due to the inferred hiatus previously discussed. When peat started to re-accumulate (i.e. during RBO-7[a]) the landscape was largely cleared, with AP:NAP ratios particularly low. This compares to RBO-6, when the pollen data suggest that although open-ground communities were important, the catchment remained dominated by woodland. Even allowing for the possibility that date AA-32296 is inaccurate, it appears that the earlier Iron Age is covered by RBO-7(a). Major deforestation clearly occurred prior to this period and most probably during the Late Bronze Age (between *ca* 3300 and 2600 BP). This would compare favourably with the evidence from much of lowland Britain, which indicates that major woodland clearance began during the Mid-Late Bronze Age (see Bell and Walker, 1995 and Roberts, 1998 for summaries). Further support is provided by the alluvial record, with the increased sediment input often observed during the Late Bronze Age/Early Iron Age generally being ascribed to intensification of arable cultivation and clearance activity (Shotton, 1978; Macklin *et al.*, 1992; Brown, 1988, 1997). It is possible that the rise in the local water table that led to renewed sedimentation within the basin was the result of increased runoff due to major woodland clearance, but this cannot be proven.

The section of the profile between 152 cm and 120 cm (*ca* 2660 and *ca* 1930 BP) is likely to correspond to the Iron Age. Non-arboreal pollen dominates the record as shown by the position of the mean subzone score amongst the open-ground taxa towards the right of the DCA plot (Figure 9.25). *Corylus avellana* and *Quercus* form the dominant arboreal types at *ca* 2-10 % TLP, with the influx data suggesting that both taxa occurred at low levels, perhaps as patches on relatively well-drained land (cf. Dark and Dark, 1997). The influx data for *Alnus glutinosa, Betula, Fraxinus excelsior, Salix,* and *Ulmus* are less clear, but suggest that the taxa were either locally sparse or absent. Poaceae undiff. is present at *ca* 20-70 % TLP and herbaceous diversity is high, with the occurrences of *Achillea*-type, Brassicaceae undiff., Chenopodiaceae undiff., *Cirsium*-type and Lactuceae undiff. indicating that open, disturbed ground was frequent. It is also likely that grassland formed an important landscape element as suggested by the consistent presences of *Centaurea nigra*-type, *Plantago lanceolata, Ranunculus acris*-type, *Rumex acetosella* and *R. acetosa. Calluna vulgaris* and *Empetrum nigrum* increase above 132 cm, perhaps indicating that the heath community expanded after *ca* 2090 BP.

Given that both species are entomophilous and low-lying and may subsequently be expected to be relatively under-represented in the pollen record, it seems likely that at least part of the input from the taxa results from growth upon the basin surface, although the dryland heath community may also have expanded.

Taken collectively the data suggest that no significant areas of woodland existed close to the site during RBO-7(a), with clearance being almost complete. It is reasonable to suggest that humans were responsible for the creation and maintenance of this cleared landscape, with much of the grassland input likely to reflect areas of pasture and/or meadow. Grains referable to the *Hordeum* and *Avena-Triticum* groups of Andersen (1979) occur throughout the proposed Iron Age section of the profile, with *Secale cereale*-type pollen also present at 152 cm and 146 cm (*ca* 2660 BP and 2490 BP). Whilst it is not possible to separate reliably *Hordeum, Avena* or *Triticum* from some wild grasses on the basis of the approaches used in this study (see chapter 5), the presence of *Secale cereale*-type pollen adds weight to the suggestion that at least some of the grains originate from domesticated taxa, and it is possible that arable cultivation occurred close to the site.

Charcoal levels are high and stable (Figure 9.22) throughout the inferred Iron Age section of the profile. Although it is likely that the long-distance component may have increased (cf. RBO-6), the data are probably also indicating a real change in the fire regime. Given the evidence for significant, presumably human, clearance activity within the pollen catchment it is likely that much of this input is reflecting anthropogenic burning.

(v) The Roman and Historical Periods; *ca* 1930-0 BP (*ca* 1890-0 cal BP)

The Roman Period is covered by the upper part of RBO-7(a) (i.e. above 118 cm). Whilst the pollen record is generally similar to that of the Iron Age, several minor changes occur in the arboreal and herb records. *Salix* and *Sorbus*-type occur at low frequencies (Figure 9.19), perhaps indicating the sparse local presence of the taxa, although it is possible that the grains could result from long-distance transport. Pollen influxes of the major arboreal taxa also increase and although this could indicate an expansion of the arboreal community, it is more likely that the data are reflecting overall increases in total pollen and spore accumulation rates (Figure 9.24). This is supported by the non-arboreal data which show similar increases in influx. When the above discussion is taken into account there is little to suggest that the area of woodland within the catchment significantly altered at the proposed transition from the Iron Age to the Roman Period.

A number of minor changes occur in the herb record, however, which could potentially signify a change in land-use. Pollen from *Artemisia*-type, *Oxyria*-type and *Rumex obtusifolius*-type is present at low levels, perhaps indicating a change in the disturbed ground (possibly field edge) component, although the data are unclear and the latter two pollen types could originate from growth amongst grassland. *Astragalus danicus*-type, *Hypericum perforatum*-type, *Ranunculus acris*-type, *Rhinanthus*-type and *Vicia sylvatica*-type also occur and *Plantago lanceolata* increases in frequency. Numerous taxa are included within these pollen types, but collectively the data suggest an expansion of the grassland (and perhaps also hedgebank) community. The presence of occasional grains of the *Hordeum*- and *Avena-Triticum* groups of Andersen (1979) and *Secale cereale*-type, along with an otherwise comparable herb flora to that found in the lower part of RBO-7(a), suggests that arable cultivation may still have been practised close to the site. Charcoal input remains high and it is likely that significant burning continued within the catchment.

The pollen record as a whole indicates that the landscape of the Roman Period was broadly similar to that of the Iron Age, with the addition of an increase in the area (or a change in location) of grassland. It seems likely that much of this grassland was present as meadow and/or pasture, possibly on the low-lying ground of the Roos Valley. The lack of an obvious decline in woodland cover across the Iron Age/Roman Period transition (cf. Dark and Dark, 1997) is likely to be in part a reflection of the almost complete absence of woodland within the catchment during the preceding Iron Age. The agricultural regime of most rural areas is also likely to have remained relatively undisturbed and unchanged by Roman rule (Allison, 1976; Cunliffe, 1988).

The end of the Roman Period broadly coincides with the start of RBO-7(b), the zone probably covering the Early-Mid Anglo-Saxon (Early Medieval) Period (*ca* 1720±50 BP [AA-32297] to *ca* 1520 BP). The arboreal record is similar to the latter part of RBO-7(a), although *Quercus* is slightly reduced and *Lonicera periclymenum* occurs sporadically (Figure 9.19), perhaps indicating its growth in scrub or as part of a hedge flora. The herb record is also similar to RBO-7(a) with several exceptions. *Hypericum perforatum*-type increases to *ca* 5-15 % TLP, *Lotus* occurs at *ca* 12-29 % between 94 cm and 98 cm (*ca* 1675-1620 BP), and *Astragalus danicus*-type and *Rhinanthus*-type are both present at *ca* 10-20 % (Figures 9.20 and 9.21). As previously argued above it is possible that the taxa signify the expansion of grassland (perhaps meadow) within the catchment. The presence of *Astragalus danicus*-type pollen (likely to originate from either *A. danicus* or *A. glycyphyllos*) suggests that this grassland may have been calcareous in nature. The high influx from the above taxa would require a large increase in the area of grassland, the habitat perhaps being frequent on the lower-lying land of the Roos Valley to the immediate south of, and surrounding, the site (Figure 3.5). An alternative possibility is that the pollen originated from plants growing at the basin edge or on the peat surface itself. However, it is difficult to envisage grassland (particularly if calcareous) growing upon the basin surface with the continuing accumulation of peat. Although Poaceae undiff. representation declines to between 4 % and 21 % and *Plantago lanceolata* is reduced to below 3 % TLP, the influx data suggest that these are largely proportional effects due to increasing inputs from the above taxa.

Taken collectively, the pollen data indicate that intense human activity continued within the vicinity of The Bog at Roos during the Early Medieval, and there is nothing to suggest that farmed plots were abandoned and woodland regenerated after the end of Roman rule (cf. Turner, 1981; Cunliffe, 1988). A similar lack of regeneration is seen in most pollen profiles located distantly from areas of particularly intense Roman activity (Dark and Dark, 1997). The data are also compatible with the suggestion of Eagles (1979) that most settlements in Humberside would have remained relatively unchanged following the end of Roman rule, unless located close to major towns or roads. Charcoal levels drop during the zone though, suggesting that decreased levels of burning (presumably anthropogenic) occurred within the catchment (cf. the Roman Period). This may be a response to a change in the location of burning (any habitation areas perhaps being located further from the site), but could also be a reflection of changing charcoal-recruitment characteristics of the basin.

Subzone RBO-7(c) covers much of the Historical Period, with deposits likely to span the Mid-Anglo-Saxon Period to *ca* 50-180 years ago, although this latter date should be taken as an approximate estimate only. There is evidence for an increase in arboreal pollen production between *ca* 1425±50 BP (AA-32301; *ca* AD 630) and *ca* 765 BP (*ca* AD 1240), with *Betula, Corylus avellana* and *Quercus* increasing in both percentage representation and absolute terms. It is not possible to identify whether this reflects the expansion of woodland or scrub, or an increase in the occurrence of isolated individuals (although the Domesday book indicates that no significant areas of woodland were located close to the site in AD 1087 [Faull and Stinson, 1986]). This increase in arboreal input is evident in the AP:NAP ratios (Figure 9.22). The occasional grains of *Fagus sylvatica* may indicate that the species was locally sparse, but could equally reflect long-distance transport. After *ca* 765 BP (*ca* AD 1240) the influx of *Corylus* and *Betula* declines, suggesting renewed clearance. Inputs from Ericaceae and *Empetrum nigrum* also decrease, suggesting a reduction in the area of heathland, and in combination with the other arboreal data perhaps indicating the clearance of areas of scrubby moor or 'waste'. Alternatively, the drop in heath input may be due in part at least to reduced growth of the taxa upon the basin surface, a suggestion perhaps supported by the rise in Cyperaceae influx values. The herb record is initially similar to that of RBO-7(b), with the exceptions of *Hypericum perforatum*-type, *Lotus, Astragalus danicus*-type and *Rhinanthus*-type which are much reduced, perhaps indicating a decrease in the area of grassland (or a change in grassland type).

Several changes occur within the non-arboreal pollen record above 64 cm (*ca* 1150 BP), indicating a shift in land-use practice. The influx of Large Poaceae pollen increases markedly (Figure 9.24), with both the *Hordeum-* and *Avena-Triticum* groups of Andersen (1979) present. *Secale cereale*-type also occurs above 54 cm (*ca* 955 BP; *ca* AD 1090), but is absent below this depth. This suggests an increase in the intensity of cultivation or a change in field location. The occurrences of *Centaurea cyanus* and Caryophyllaceae undiff. pollen above 64 cm presumably reflect the presences of the taxa as arable weeds (Hauf, 1983). Taxa characteristic of grassland (e.g. *Astragalus danicus-*

type and *Rhinanthus*-type) also increase between 60 and 36 cm (particularly between 54 and 48 cm) and it is probable that the grassland community expanded between *ca* 1070 BP (*ca* AD 960) and *ca* 610 BP (*ca* AD 1340).

Cannabis-type pollen is consistently present at low levels between 58 and 16 cm (*ca* 1030 BP [*ca* AD 1000] and 230 BP [*ca* AD 1770]). Although the low number of grains did not permit statistical analysis (cf. Whittington and Gordon, 1987), most grains had protruding pores characteristic of *Cannabis sativa* (Table 9.6). It is possible that the bulk of the pollen type originates from hemp, with the data suggesting it may have been cultivated at low frequencies within the catchment during the above period (cf. Sproatley Bog, section 8.5).

The high charcoal levels throughout RBO-7(c) support the hypothesis of increased human activity during the subzone. Fragments are extremely frequent between 80 and 68 cm (*ca* 1445 BP [*ca* AD 600] and 1225 BP [*ca* AD 825]) and this may reflect *in-situ* burning of the basin vegetation. *Osmunda regalis* spores become abundant coincident with the increase in charcoal input (Figure 9.21), and it is possible that royal fern proliferated on the basin surface in response to the hypothesised burning events. There is nothing to suggest that the spores were artificially concentrated due to post-depositional pollen loss (Figure 9.2 and section 9.4.1.2).

Dating of RBO-7(d) is difficult, but it is likely that the subzone covers the last *ca* 50-180 years. The sub-fossil record seems to be dominated by pollen from the on-site community, with the increasing *Betula* representation between 12 cm and 4 cm likely to originate from the *Betula* woodland that Beckett (1975) reported to be growing upon the basin surface prior to 1968. Above 4 cm, the record suggests a community very similar to that described in section 3.4.4 as part of the on-site vegetational survey, and little information concerning the wider catchment can be extracted. Despite the presence of carr on the site on at least two occasions in the last 30-35 years and the reservations outlined in section 3.4.4, the sharpness of the changes evident in the upper 20 cm of the deposit indicate that mixing by roots has been minimal.

(vi) Comparison with previous studies from the site

A core from the site has previously been investigated by Beckett (1975, 1981). The results of this study are in general agreement with his data, although the higher resolution sampling and dating strategy employed has revealed a great deal of additional information. There are several differences between the data, however. Beckett reports *Pinus sylvestris* at *ca* 10-30 % TDLP (total dryland pollen) during the earliest Holocene and *Quercus* at <10 % TDLP throughout the Holocene section of the profile. This compares to data from the present study where *Pinus sylvestris* does not exceed 7.8 % TLP and *Quercus* representation is between 15 % and 40 % TLP. These variations are likely to be related to differences in core location, and subsequently the pollen depositional characteristics of the basin. As the variation in *Quercus* representation persists throughout the peat and gyttja sections of the core it does not seem to be related to differences in core stratigraphy. It is perhaps more likely that the core used in this study was located in a slightly less central position than that of Beckett, although the density of vegetation on the site meant that this could not be ascertained. The main trends of the two *Quercus* curves are similar between cores, the differences outlined above having no significant affect on the interpretation of the pollen record.

A number of differences also occur at the top of the core (e.g. *Betula* and *Alnus glutinosa* representation) and are likely to be reflect variation in both sediment accumulation rates (and perhaps sedimentation periods) and the composition of the on-site vegetation (which appears to dominate the upper part of the record; see above).

(vii) Summary

The pollen record suggests that the landscape surrounding The Bog at Roos was predominately wooded during the Early-Mid Holocene. Although dating controls are not optimal, there is evidence for considerable disturbance of woodland between *ca* 4790 and *ca* 4390 BP. Whilst natural causes cannot be eliminated entirely, it seems likely that this reflects the activity of Neolithic peoples and it is possible that arable cultivation was carried out close to the site during this period. There is evidence for woodland recovery after this date, although open areas persisted within the catchment until a sedimentary hiatus occurred (possibly at *ca* 3380 BP). When peat began to re-accumulate at *ca* 2660 BP, the landscape was almost entirely cleared. It is likely that major clearance occurred prior to the Early Iron Age, perhaps during the Late Bronze Age. The upper part of the sedimentary sequence covers most of the Iron Age, Roman and Historical Periods and provides the most complete record of vegetational change presently available from Holderness. Several periods of landscape continuity and change are evident both across and within these major cultural divisions.

A summary of the development of the landscape around The Bog at Roos is presented in Table 9.8.

Chapter 10: Synthesis and evaluation

10.1 Introduction

This chapter presents a synthesis of the results and conclusions of the project. The Holocene vegetational history of central Holderness is summarised in section 10.2 and several key issues are discussed. Section 10.3 reviews the evidence for human activity within the palaeoenvironmental records obtained, and the results of the pollen preservation analyses are synthesised in section 10.4. Finally, an evaluation of the success of the project and suggested areas for future research are presented in section 10.5.

10.2 The Holocene vegetational development of central Holderness and comparison with surrounding regions

10.2.1 The Holocene vegetational development of central Holderness with notes on the terminal Late-Glacial

This section presents a summary of the vegetational development of central Holderness, with particular emphasis upon similarities and variations in vegetation composition between the study sites through time. Detailed vegetational histories are presented in the relevant site results chapters. Whilst the discussion centres upon the Holocene, a brief outline of the terminal Late-Glacial vegetational development of the catchment of Sproatley Bog is also given. Summaries of the vegetational histories of the site catchments are presented in Tables 10.1 and 10.2, and the initial expansion dates of the main arboreal taxa are given in Table 10.3. The charcoal records from each site are shown in Figures 10.1 and 10.2.

(i) The Upper Palaeolithic; *ca* post-11,000-10,200 BP (*ca* post-13,000-11,520 cal BP)

Only the profile from Sproatley Bog was analysed during this period which limits discussion of the Younger Dryas vegetational development to this site. The data indicate that the vegetation within the pollen catchment was open during the Younger Dryas Stadial and dominated by grassland (Table 10.1 and section 8.5). Low levels of *Betula* (both dwarf and tree forms), *Salix* and *Juniperus* scrub occurred and it is likely that spatially-restricted areas of heath were also present. The high proportion of clay within the profile indicates that soils within the catchment were unstable and prone to erosion and it is likely that the extremely high charcoal levels (Figure 10.1) predominately reflect inputs of reworked fragments. Natural burning of the open steppe and scrub vegetation may also have occurred.

(ii) The Early Mesolithic; *ca* 10,200-8600 BP (*ca* 11,520-9580 cal BP)

The Early Mesolithic is covered by the profiles from all four study sites. During the earliest Holocene the pollen records from each site are broadly similar. Tree birches (probably *Betula pendula, B. pubescens* and/or their hybrid) expanded soon after *ca* 10,200-10,100 BP, presumably in response to the onset of more favourable climatic conditions at the start of the Holocene. Poor dating controls mean that it is difficult to estimate the durations of these expansions, but it is likely that *Betula* woodland covered much of central Holderness during the earliest Holocene. *Salix* is also likely to have been frequent, perhaps as part of a mixed *Betula-Salix* scrub or woodland. The canopy was relatively open and/or discontinuous, with damp grassland communities containing *Filipendula* and *Ranunculus* spp. and ferns within the understorey. Low levels of *Juniperus communis, Calluna vulgaris* and *Empetrum nigrum* also occurred. It is clear from the percentage LOI data that the development of these vegetation communities led to decreased soil erosion (although the data are probably also reflecting greater within-basin productivity). The high charcoal to pollen ratios prior to *ca* 9600-9500 BP are likely to result primarily from the erosional input of reworked particles, as discussed in detail in chapters 6-9. Taking this into account it is unlikely that fire (whether natural or anthropogenic) played a major role in determining the vegetation composition of central Holderness during the earliest Holocene, although limited burning may still have occurred.

Open *Betula/Betula-Salix* woodland dominated the site catchments until the local expansion of *Corylus avellana.* At Cess Dell, Sproatley Bog and The Bog at Roos (but not at Gilderson Marr) a marked, but apparently short-lived contraction occurred within the early part of the *Corylus avellana* expansion, with the taxon becoming locally sparse or absent and open *Betula* woodland recovering to form the primary vegetation type (see section 10.2.4). Assigning dates to the *Corylus avellana* expansions is problematic. A total of seven radiocarbon dates of between 9680 BP and 9480 BP were obtained from samples located throughout the *Corylus avellana* rises (Table 10.4; a further two dates are felt to be too young). Whilst at face value this may suggest that expansion of the taxon occurred at similar times within each catchment and was rapid, it is quite possible that the dates all lie upon the radiocarbon plateau centred around 9600-9500 BP, which covers approximately 400 calendar years (Becker and Kromer, 1993; Stuiver and Reimer, 1993). The expansions could thus have occurred at significantly different times, but this would not be obvious. It seems likely that the initial increases and subsequent contractions at Cess Dell, Sproatley Bog and The Bog at Roos occurred early within (or possibly immediately prior to) the radiocarbon plateau and that the subsequent sustained *Corylus* expansions took place later within the plateau. The lack of an obvious contraction within the early part of the *Corylus avellana* curve at Gilderson Marr may indicate that the taxon started to expand later within the pollen catchment (cf. the other study sites, but see section 10.2.4).

Calculating accurate estimates of the minimum durations of the *Corylus avellana* expansions is consequently difficult, but it appears that the replacement of *Betula*-dominated by *Corylus avellana*-dominated woodland occurred within *ca* 180-260 ^{14}C years (Table 10.3). Competitive exclusion by the expanding hazel populations resulted in reductions in the frequencies of *Betula* and *Salix* at all sites, and also *Juniperus communis* and *Empetrum nigrum* at Cess Dell, Gilderson Marr and The Bog at Roos. It is interesting that juniper persisted (albeit at low levels) until the hazel rise at three of the study sites, as the taxon was apparently outcompeted earlier at Sproatley Bog and

Star Carr (Day, 1995) by *Betula*. The overall low charcoal levels during the sustained hazel rise do not support the suggestion of Smith (1970) that the dominance of the taxon was related to increased levels of burning.

From *ca* 9500 BP *Corylus avellana* woodland dominated the site catchments with *Ulmus* initially occurring at low levels, but becoming increasingly important with time (but see below), and *Betula, Viburnum* (presumably *V. opulus*) and arboreal Rosaceae present as minor components of the vegetational mosaic. The overall low levels of open and disturbed ground herbs in conjunction with the relatively high AP:NAP ratios indicate that woodland cover was probably relatively complete.

The absolute data suggest that *Ulmus* began to expand locally at Cess Dell, Gilderson Marr and The Bog at Roos coincident with the sustained rise in *Corylus avellana* influx, with expansion complete within *ca* 400-480 ^{14}C years. The similarities of the expansion durations at these sites suggest that the competitive ability of the genus was equivalent in all three catchments, which may indicate that soil and ecological conditions were also broadly comparable. Although *Ulmus* may have been locally present at low levels at an earlier date within the catchment of Sproatley Bog (coincident with the initial [cf. sustained] *Corylus avellana* rise), major expansion of the genus did not occur until *ca* 8965 BP. It is likely that this delay was caused by the combination of adverse climatic conditions and high levels of vegetational disturbance (see section 8.5).

The next major compositional change occurred with the local expansion of *Quercus* (probably *Q. robur*; see section 6.5), with pedunculate oak likely to have been frequent on the clayey soils of central Holderness. The taxon expanded at broadly similar times within each catchment, with dates for an initial local presence only varying slightly between *ca* 9150 BP and *ca* 8940 BP (Table 10.3). Minimum estimates for the durations of the expansions vary between *ca* 360 ^{14}C and *ca* 525 ^{14}C years (Table 10.3). The influx data suggest that the expansion of *Quercus* reduced the local populations of *Betula* and *Corylus avellana* at all sites, along with *Ulmus* at Cess Dell, Gilderson Marr and perhaps The Bog at Roos, and *Salix* at Sproatley Bog. Mixed *Quercus-Ulmus-Corylus* woodland is likely to have dominated the vegetational landscape of central Holderness until the expansions of *Alnus glutinosa* and *Tilia* (see Table 10.1 and below). *Betula* occurred at low levels (perhaps as a gap-phase taxon) and *Fraxinus excelsior* and *Hedera helix* were also present. It is likely that *Fraxinus excelsior* was largely confined to wetter soils, canopy openings or the woodland edge. The high AP:NAP ratios and low herbaceous diversities suggest that woodland cover was relatively complete at all sites, although some variation is evident, with significant influx from heathland taxa at Gilderson Marr from *ca* 8140 BP.

(iii) The Late Mesolithic; *ca* 8600-5500 BP (*ca* 9580-6310 cal BP)

The Late Mesolithic is covered by the profiles from Cess Dell, Gilderson Marr and The Bog at Roos. In addition, the profile from Sproatley Bog covers the first *ca* 600 ^{14}C years of the period. The next major compositional change occurred with the expansions of *Alnus glutinosa* and *Tilia.* Dates for the expansions of the two taxa are highly diachronous (Table 10.3) and probably reflect local variations in ecological (perhaps soil) conditions (cf. Chambers and Elliott, 1989; Bennett and Birks, 1990). How much of the apparent diachroneity between sites is a result of dating inaccuracies is uncertain, but if the dates and interpolations are valid then the differences in expansion times between sites mean that a mosaic of vegetation types will have existed within central Holderness between *ca* 7800 BP and 7000 BP (when expansion of the two taxa was complete at all sites). A suite of site-specific vegetation changes occurred coincident with the expansions (see Table 10.5). It is likely that the differences in vegetational response reflect the interplay of competitive exclusion, site-specific disturbance regimes and possibly climatic deterioration. Whatever the cause(s) of the different responses, it is clear that the flora of each catchment underwent a series of wider compositional changes immediately before and during the period covered by the initial *Alnus glutinosa* and *Tilia* expansions. Environmental conditions during this period are discussed in more detail in section 10.2.4.

Mixed woodland containing *Alnus glutinosa, Quercus, Ulmus, Tilia* and *Corylus avellana* as common components, and *Fraxinus excelsior* and *Betula* at lower levels dominated the catchments of Cess Dell and The Bog at Roos between *ca* 7000 BP and 6160 BP. Given that *Tilia* pollen is poorly dispersed (Greig, 1982; Huntley and Birks, 1983) and is produced in low amounts (Andersen, 1973), it is likely that the genus was frequent and perhaps even dominant within the woodland of central Holderness. Although woodland cover remained relatively complete around The Bog at Roos until *ca* 5290±90 BP (AA-32293), disturbance increased within the catchment of Cess Dell from *ca* 6160 BP, with *Corylus avellana* and *Ulmus* reduced and grassland and damp ground communities important. The possibility remains that the radiocarbon date of 6105±65 BP (AA-30876) obtained from the upper part of the Cess Dell profile may be artificially old in which case this period of increased disturbance may be Early Neolithic (rather than Late Mesolithic) in age. At Gilderson Marr considerable disturbance and fragmentation of the woodland canopy occurred between *ca* 7200 BP and 6005 BP, with open, disturbed and damp ground communities important (see section 7.5). Despite this, mixed woodland is likely to have remained frequent within the catchment.

A degree of local variation thus existed within the vegetational mosaic of central Holderness during the later Mesolithic as a result of variability in the expansion times of *Alnus glutinosa* and *Tilia*, differences in ecological interactions during the expansions, and the presence of prolonged disturbance events within the catchments of Cess Dell and Gilderson Marr.

(iv) The Neolithic; *ca* 5500-3700 BP (*ca* 6310-4060 cal BP)

The Neolithic is covered, at least in part, by the profiles from Gilderson Marr and The Bog at Roos. The first significant vegetation change occurred with the major local decline of *Ulmus,* an event dated as *ca* 5445±75 BP (AA-32310) at Gilderson Marr and *ca* 5290±90 BP (AA-32293) at The Bog at Roos. Whilst the date from The Bog at Roos just falls within the age range of 5300-5100 BP suggested for the traditional 'elm decline' by Smith and Pilcher (1973), the date from Gilderson Marr lies outside of this range and it is possible that it is artificially old (see section 7.5). Alternatively the dates may both be accurate which would suggest that an elm decline occurred earlier within central Holderness than over much of England, although conclusions must remain tentative (similarly early dates have also been obtained for the event in northern England [Bartley *et al.,* 1976; Hibbert and Switsur, 1976]).

There is no evidence that the genus ever recovered within the catchment of The Bog at Roos with population levels also remaining consistently low at Gilderson Marr until the record ceases at *ca* 4190 BP. Environmental conditions clearly prevented re-establishment of the taxon within the catchments. At Gilderson Marr, it is possible that anthropogenic disturbance played a major role in preventing regeneration. Although the lack of clear evidence for human activity prior to *ca* 4790 BP at The Bog at Roos suggests that natural competitive interactions may also have been important, human activity that was invisible in the pollen record could also have occurred.

A number of wider vegetation changes occurred coincident with the decline in *Ulmus*, with variation again evident between sites. At The Bog at Roos *Tilia* influx declines and it is likely that the genus was reduced to very low levels or became absent from the catchment until *ca* 4790 BP. The pollen data suggest that negligible wider disturbance of the woodland canopy occurred coincident with these declines, although an increase in the area of open ground and heathland occurred later in the record (from *ca* 4790 BP to *ca* 4390 BP). In comparison, *Tilia* appears to have expanded coincident with the elm decline at Gilderson Marr and there is considerable evidence for wider possibly human disturbance of the vegetational mosaic (see 10.3.1). It is likely that a mosaic of open ground, heath and mixed woodland existed within the catchment until *ca* 4190 BP.

The available data thus suggest that local variation in vegetation composition continued to occur for much of the Neolithic, primarily as a result of differences in disturbance intensity between sites. There is complementary evidence for spatial variation in fire regime, with charcoal levels high at Gilderson Marr, but low at The Bog at Roos (except between *ca* 4790 BP and *ca* 4390 BP when input was moderate). The charcoal record during the Neolithic is discussed in detail in section 10.3.2.

(v) The Bronze and Iron Ages

Discussion of the earlier part of the Bronze Age and the Iron Age is limited to the profile from The Bog at Roos. It is possible that the record covers the bulk of the Early Bronze Age (*ca* 3700-3380 BP), but in view of the dating problems within this part of the profile (discussed in section 9.5) the following summary should be viewed with caution. The pollen data indicate that whilst mixed woodland remained frequent, increased disturbance occurred within the dryland vegetation, with *Quercus* and *Corylus avellana* reduced and *Betula* increased in frequency. It is likely that open ground (primarily grassland) and heath communities expanded as a result of this change in the disturbance regime. Charcoal levels also increase at the inferred start of the Bronze Age suggesting that burning became more frequent or intense within the catchment.

The presence of a prolonged sedimentary hiatus means that the later Bronze Age is probably not represented. When sediment began re-accumulating after *ca* 2660±50 BP (AA-32296; close to the start of the Iron Age, see Appendix 1) it is clear that the landscape was almost entirely deforested, with any woodland likely to have been fragmented and of limited spatial extent. Taken as a whole, the pollen and AP:NAP data from The Bog at Roos indicate that open ground communities dominated the catchment vegetation with grassland particularly frequent. Heathland communities were also important, although at least part of the influx from heath taxa is likely to reflect on-site growth. In a review of 41 pollen diagrams from England with profiles covering the Iron Age, Dark and Dark (1997) concluded that most of the site catchments contained a mixture of woodland and open ground (composed of varying proportions of grassland, arable ground and frequently heath). Only four of these diagrams had arboreal pollen contributions of <25 % of the total pollen sum and two of these records were argued to be dominated by pollen from locally growing wetland taxa (*ibid*). Total arboreal input never exceeds 15 % TLP during the Iron Age section of the profile from The Bog at Roos, and is generally <10 % TLP. At face value this suggests that the catchment was cleared more extensively than the areas represented by most of the pollen diagrams reviewed. Conclusions must remain tentative though given the likely variations in pollen recruitment characteristics and basin locations (in relation to cleared or wooded environments) between sites.

(vi) The Roman and Historical Periods

The Roman and Historical Periods are covered by the profile from The Bog at Roos, with the sequence from Sproatley Bog also covering part of the Early Medieval Period (and perhaps part of the Roman Period, but this is felt unlikely; see section 8.5). The pollen record as a whole indicates that the landscape during the Roman Period was broadly similar to that of the Iron Age, with open ground frequent and any woodland or scrub likely to have been scarce. Several minor changes occur in the disturbed ground component though perhaps indicating changes in land-use practice. The area of grassland increased during the period, possibly as meadow within the low-lying Roos Valley (see section 9.5).

At The Bog at Roos, the pollen record during the Early Medieval Period is initially similar to that of the preceding Roman Period and it is likely that the catchment remained almost totally deforested. After *ca* 1425±50 BP (AA-32301; *ca* AD 630) it is possible that the area of scrub expanded slightly, with *Betula, Corylus* and *Quercus* more frequent, although the record could also be reflecting an increase in the number of isolated individuals. The area of grassland initially decreased following the expansions of these taxa, but recovered after *ca* 1070 BP (*ca* AD 960). It is likely that a broadly similar vegetational environment existed within the catchment of Sproatley Bog during the earlier part of the Anglo-Saxon Period (prior to *ca* 1210±40 BP [AA-3088]; *ca* AD 830), with trees and shrubs largely absent, although the area seems to have been more intensely cultivated (see sections 8.5 and 10.3.1). After *ca* 765 BP (*ca* AD 1240) the area of heath and scrub declined at The Bog at Roos and the landscape became almost entirely cleared. Several changes within the herb record after this date seem to reflect fluctuations in the relative areas (or locations) of grassland and cultivated ground, with variation in land-use occurring until the present day.

(vii) Concluding comments

Whilst the pollen records from the four study sites are generally similar, it is clear that limited variation in vegetation composition was a feature of central Holderness during the Early-Mid Holocene, particularly from the Late Mesolithic onwards. Although only one profile was obtained for the Late Holocene, this pattern may perhaps be expected to have continued for much of the period. Following expansion, the representations of the arboreal taxa are broadly similar between sites and there is nothing to suggest that any of the major species were more frequent within one catchment than the others (as far as can be told). The exception to this is *Alnus glutinosa* which is generally present at *ca* 15-25 % TLP at Gilderson Marr and The Bog at Roos, but frequently reaches values in excess of 50 % TLP at Cess Dell. It is likely that the higher representation of the taxon at Cess Dell was a result of its growth upon the basin surface.

10.2.2 Comparison with the wider region

This section provides a comparison of the vegetational development of central Holderness with selected areas of eastern England (particularly the lowlands) in order to allow the data to be placed into a regional context.

Comparison of the pollen records obtained with those available from the rest of Holderness is hampered by the absence of securely dated diagrams. This does not allow variation in the timings of most of the major vegetation changes to be assessed, although a number of general conclusions concerning differences in vegetation composition can be made. The most useful pollen records available for comparison from within the undulating land surface of eastern and northern Holderness are those from Gransmoor and Hornsea Old Mere (Beckett, 1975, 1981), Skipsea Withow Mere (Blackham and Flenley, 1984) and Brandesburton (Clark and Godwin, 1956).

Although the records are similar to those from the study sites in terms of the dominant species involved, there appears to be considerable variation in the order of migration of the taxa. For example, *Ulmus, Quercus* and *Alnus glutinosa* appear to expand relatively synchronously at Skipsea Withow Mere, with *Tilia* becoming locally present shortly afterwards. *Ulmus* and *Quercus* also appear to have expanded together at Hornsea Old Mere and it is possible that *Alnus glutinosa* became locally present at low levels at a similar time, although major expansion did not occur until later. Unlike Skipsea Withow Mere, the expansion of *Tilia* seems to have occurred a considerable time after the *Alnus* rise. The early Holocene record is missing from Gransmoor, but it is clear that *Ulmus* and *Quercus* expanded considerably earlier than *Alnus glutinosa* within the catchment of this site. Whether these apparent variations reflect real differences in migration rates or migrational order, or are related to sedimentary regimes or the low sampling resolutions employed in the former studies is impossible to say given the lack of dating controls. It is possible though that the pattern of migration observed at the thesis sites does not apply to the rest of Holderness.

Several other conclusions can be made. The high levels of *Tilia* pollen at Gransmoor and Brandesburton (reaching *ca* 60 % total arboreal pollen at Gransmoor; Beckett, 1975) suggest that the genus was by far the most frequent woodland component on the sand- and gravel-derived soils of these areas for a considerable part of the Holocene (as previously suggested by Beckett, 1975 and Dinnin, 1995). Unfortunately it is not possible to assign a date range to this period of dominance, but at Gransmoor the taxon declines markedly after *ca* 5100 BP. It is clear though that *Tilia* was far more frequent in this area than in central Holderness. Whilst absent or locally rare in central Holderness, it is likely that stands of *Pinus sylvestris* grew close to both Gransmoor and Hornsea Old Mere during the Early Holocene. The Holocene distribution of the taxon within Holderness was probably closely linked to the distribution of sandy soils, with the species competitively inferior to broad-leaved trees on the more abundant clay-based soils.

It is likely that the drier areas of the Hull Valley were dominated by similar vegetation types to central Holderness during the Early-Mid Holocene. Some support for this is provided by a pollen record from Routh Quarry, which indicates that mixed *Tilia*-based woodland was dominant from *ca* 7500 BP until after *ca* 3460 BP (Lillie and Gearey, 2000). The authors also suggest that *Tilia* formed a fringing woodland at the floodplain edge until major deforestation occurred (probably during the Bronze Age). Similar *Tilia*-based communities are thought to have existed on the drier terraces at the edges of other river valleys in lowland England (e.g. Greig, 1982; Brown, 1988; Brown, 1997a). A wider range of vegetational communities is likely to have existed within the Hull Valley during the Holocene than in central Holderness due to the greater variation in soils existing in the former area. For example, *Betula* appears to have remained important throughout the Holocene on damper soils and *Pinus sylvestris* may have been locally common on unstable sandy substrates (Lillie and Gearey, 2000). It is also likely that significant areas of *Alnus-Salix* carr and reedswamp existed for much of the Holocene in particularly poorly drained, low-lying areas and brackish water and saltmarsh communities will have occurred along the tidal reaches of the River Hull. Wet grassland is also likely to have been important during the later Holocene.

The absence of reliable pollen records from the Yorkshire Wolds means that comparison with the vegetational development of the area is difficult. It seems likely that woodland was important across much of the region, at least until the Early Neolithic, when the abundance of monumental archaeology (and limited molluscan palaeoecological data; see sections 2.2.2.2 and 2.3.2) indicates that significant areas of open ground existed. Given that the soils are likely to have been shallow and chalk-rich, *Fraxinus excelsior* may be expected to have occurred at greater frequencies than in Holderness. This is in agreement with Bennett (1989) who suggests that the area would have been dominated by *Fraxinus excelsior* woodland, with *Corylus avellana* frequent and some *Ulmus* (and perhaps *Taxus baccata*) occurring at *ca* 5000 BP. Areas of open scrub and grassland are also likely to have existed throughout the Holocene on unstable valley floors (Bush and Flenley, 1987; Bush, 1988, 1993; and see section 2.3.2.2).

There is a great deal of similarity between the Early-Mid Holocene records obtained from central Holderness and those available from the Vale of Pickering in terms of vegetation composition, although there are also several notable differences. These are primarily due to variations in the expansion times of the major arboreal taxa, for example *Corylus avellana* and *Ulmus* did not expand at Star Carr until *ca* 9000 BP (Day, 1995; Dark, 1998a). *Quercus* also reached the area later, not expanding until at least *ca* 8400 BP. It is likely that these later expansion dates (cf. central Holderness) reflect the presence of less suitable soil conditions within the catchment of Lake Flixton and/or slower colonisation routes to the Vale of Pickering (cf. central Holderness). Finally, *Tilia* does not exceed 1 % TLP prior to *ca* 6500 BP, but is consistently present at low levels from at least *ca* 7500 BP (Day, 1995; Dark, 1998b). This suggests that *Tilia,* although present, was not a major canopy component around Lake Flixton prior to *ca* 6500 BP.

There is also a high degree of similarity between the records obtained in this study and those from within areas of East Anglia having predominately till-based soils (e.g. The Mere, Stow Bedon [Bennett, 1986], Saham Mere and Sea Mere [Bennett, 1988]). Several differences occur again though, with *Corylus avellana* apparently expanding later in East Anglia and with *Fraxinus excelsior* and *Fagus sylvatica* more frequent than in central Holderness.

More obvious differences emerge when pollen records from further north and higher elevations are considered. For example, short-lived peaks in *Hippophaë rhamnoides* and *Juniperus communis* occur during the earliest Holocene on the lower fringes of the North York Moors (Simmons *et al.,* 1993) and in County Durham (Bartley *et al.,* 1976), probably reflecting the later expansion of *Betula* within the areas. It is likely that *Pinus sylvestris* was far more frequent in many areas of northern (e.g. the North York Moors, Simmons *et al.,* 1993) and western Yorkshire (e.g. the Craven District, Bartley *et al.,* 1990) than in the study area. The expansions of the major broad-leaved taxa also seem to have occurred later than in Holderness, with significant areas of mixed *Corylus-Quercus-Ulmus* woodland only developing on the lower fringes of the Moors from *ca* 7000 BP (Jones *et al.,* 1979; Simmons *et al.,* 1993). Differences in vegetation composition are even more marked on the higher Moors (see section 2.2.2.2 for review). The above differences can largely be explained by variations in the dominant soil types and climatic regime with altitude and latitude.

As a summary although local variations are evident, particularly with respect to the expansion times of the major arboreal taxa, the vegetational development of central Holderness is broadly similar to that of other low-lying areas of eastern England with till-based soils (e.g. East Anglia and The Vale of Pickering). Greater differences are seen when the data are compared to records from northern England and upland areas.

10.2.3 Holocene Regional Pollen Assemblage Zones (RPAZs): an assessment

RPAZs covering the Holocene vegetational development of the Holderness plain have been proposed by Beckett (1981) and are outlined in Table 10.6. Several problems have been identified concerning the usefulness of the RPAZs in their current state. Perhaps most importantly, until now few radiocarbon dates have been available and although tentative age ranges have been suggested by Flenley (1987; Table 10.6), the RPAZs are effectively undated (Dinnin, 1995). The zoning scheme also assumes that the principal vegetation changes occurred at similar times across the region, which is perhaps unlikely and certainly untestable in the absence of dating controls. Finally, the pollen data indicate that local variations in vegetation composition are likely to have existed within the region (Flenley, 1987; Dinnin, 1995 and see above), questioning the applicability of a RPAZ system. The data obtained during this study provide absolute dates for all but one of the key vegetation changes upon which the RPAZs are based and allow a number of points to be made concerning the applicability of the zones. Each assemblage zone is assessed in turn before concluding comments are made. Details of the correlation between the LPAZs assigned during this study and the RPAZs of Beckett (1981) are provided in Table 10.7.

(i) *Betula-Pinus*

Dates for the opening of this RPAZ are likely to have been fairly uniform across Holderness, at least upon till-based soils which appear to have been immediately suitable for colonisation by locally occurring *Betula* populations following climatic amelioration. The ages of 10,120±180 BP (Birm-405; Beckett, 1975) and *ca* 10,170 BP both obtained from The Bog at Roos provide reliable dates for the opening of the assemblage zone. All of the records from Holderness that cover the earliest Holocene show a similar *Betula* maximum and the zone is likely to apply to most (if not all) sites located in morainic Holderness. The zone ends with the increase of *Corylus avellana*-type pollen to >50 % TLP. Several points can be made regarding this zone boundary.

Firstly, two Early Holocene expansions are evident in the hazel curves from Sproatley Bog, Cess Dell and The Bog at Roos (an initial arrested expansion and a later sustained population increase; see section 10.2.1). Given that hazel only exceeds 50 % TLP during the initial expansion at Sproatley Bog (reaching a maximum of ~40 % TLP at The Bog at Roos and Cess Dell) and that the hazel rise is continuous at Gilderson Marr, it is perhaps most appropriate to assign the zone boundary to the start of the sustained *Corylus avellana*-type increase. This dates the end of the RPAZ as *ca* 9500 BP within all of the study sites, although it should be remembered that the calendar age of the event may be somewhat more variable (see 10.2.1). Whilst it should not be assumed that the date of *ca* 9500 BP is applicable across all of Holderness, on the basis of the available evidence, this seems a reasonable suggestion.

(ii) *Corylus/Myrica-Ulmus*

This zone opens with the hazel rise and incorporates the local expansions of both *Quercus* and *Ulmus*. The opening date of *ca* 9500 BP seems reasonable (see above), although assigning an end date is more difficult, the zone being delimited by the expansion of *Alnus glutinosa*. This event is likely to have been determined primarily by site-specific factors and was probably highly time-transgressive across Holderness. Dates from the study sites range from *ca* 7840 BP to *ca* 7200 BP, with the mean age calculated as *ca* 7500 BP. These estimates serve as a guide only and it is perhaps most appropriate to present the end date of the zone as an age range, rather than a specific date. The zone is represented in all pollen records covering this period except Skipsea Withow Mere (Blackham and Flenley, 1984), where *Alnus glutinosa, Quercus* and *Ulmus* increase at similar depths within the profile. Given that alder expands considerably later than both oak and elm at all other sites, the reliability of this record is uncertain as the occurrence of a depositional hiatus immediately prior to the apparent expansions could account for the pollen record.

(iii) *Alnus-Ulmus*

As mentioned above the start date of this zone is likely to have been highly variable. The zone ends with the decline of *Ulmus* to <5 % TLP, taken as the traditional elm decline and dated between *ca* 5400-5100 BP in Holderness (although the earliest date may be artificially old). Several points can be made. Firstly, *Ulmus* falls below 5 % TLP sporadically throughout much of the Early-Mid Holocene in the profile from Gilderson Marr and it may be that a sustained drop in *Ulmus* representation is a more appropriate way to define the end of the zone. Secondly, as also demonstrated by the profile from Gilderson Marr, an earlier decline in elm coincides with the alder rise (zone GM-5), and the pollen record for this LPAZ has all of the characteristics of the *Alnus-Quercus* zone. Consideration of the entire profile clearly places the LPAZ within the *Alnus-Ulmus* RPAZ, but if the lower part of the record was missing (i.e. prior to the alder rise) then the LPAZ would be referred to the wrong RPAZ. Finally, it is misleading to exclude *Tilia* representation from the pollen summary of this zone (Figure 10.6) as the taxon is likely to have been frequent, perhaps even dominant, across much of Holderness during this period. At Gransmoor the genus is the dominant arboreal type.

(iv) *Alnus-Quercus*

This zone covers the period from the elm decline until the increases of both Poaceae and *Plantago lanceolata* pollen to >5 % TLP. The zone starts at *ca* 5400-5100 BP and ends with the beginning of major woodland clearance. No satisfactory dates are available for the end of the zone, with The Bog at Roos the only study site with a record covering the latter part of the period. At this site, the zone clearly ends prior to 2660±50 BP (AA-32296) and probably after *ca* 3380 BP. As stated by Dinnin (1995), clearance activity is likely to have varied in time and space, but at present little more can be said.

(v) *Alnus*-Poaceae (formerly *Alnus*-Gramineae)

This is the final assemblage zone and covers the period from the increases of both Poaceae and *Plantago lanceolata* pollen to >5 % TLP until the present day. The problems discussed above for the *Alnus-Quercus* assemblage zone apply equally for this zone and the RPAZ remains poorly dated. It is likely that the zone starts somewhere between *ca* 3380 BP and 2660±50 BP (AA-32296), that is during the Mid-Late Bronze Age. Unfortunately the scarcity of known sites in Holderness with records covering this period means that the zone is likely to remain poorly dated.

Two general conclusions can be made. Firstly, little emphasis should be placed on the levels of herbaceous pollen input during the *Corylus/Myrica-Ulmus*, *Alnus-Ulmus* and *Alnus-Quercus* assemblage zones (particularly the latter), as this study has shown that herb levels are highly variable in time and space during the periods covered by these zones. This is largely as a result of variations in the disturbance regime. Secondly, there are clear variations in the start and end dates of several of the zones, a problem that is likely to be more marked when dates from the whole of Holderness become available. Due to this, the start and end dates of at least some of the zones (see above for detail) should be viewed as estimated age ranges, rather than exact dates.

In order for RPAZs to be valid they must be based upon a number of LPAZs from a series of sites across a region which show overall similarity in pollen and spore content at equivalent times (Bennett, 1988). Whilst this may be the case, dated profiles from beyond the region of central Holderness would need to be considered before secure conclusions could be made. At present, the results of this study can only be used to suggest that the RPAZs are broadly applicable to central Holderness (although there is variation in the start and end dates of several of the zones). The results of the radiocarbon dating programme provide a more secure chronology for the RPAZs and refine the estimated age ranges of Flenley (1987). The above data thus provide a starting point for assessment of the RPAZs proposed by Beckett (1981), rather than a completed evaluation. A summary of the proposed age ranges of the RPAZs within central Holderness is provided in Table 10.8.

10.2.4 Events at and around the *Corylus avellana* and *Alnus glutinosa* rises: evidence for climatic fluctuation during the Early Holocene?

(i) The *Corylus avellana* rise

Recent investigations have shown that the earliest Holocene (cf. the Pre-Boreal period) in Europe was characterised by fluctuating climatic conditions and that temperature change was not unidirectional following the end of the Younger Dryas (e.g. Atkinson *et al.*, 1987; Lowe *et al.*, 1994; Walker *et al.*, 1994; Björck *et al.*, 1996; Whittington *et al.*, 1996; Björck *et al.*, 1997; Edwards and Whittington, 1997). Of particular interest to this study is the Pre-Boreal Oscillation (PBO), a period of cool conditions in Europe lasting *ca* 150 calendar years and dated to between 11,300-11,150 cal BP (i.e. between the radiocarbon plateaux at *ca* 10,000-9900 BP and *ca* 9600-9500 BP; Björck *et al.,* 1997). As previously discussed in chapters 6, 8 and 9, it is likely that the marked contractions seen early within the *Corylus avellana* curves from Cess Dell, Sproatley Bog and The Bog at Roos reflect deteriorating climatic conditions associated with this event. The absence of a contraction within the hazel curve from Gilderson Marr is intriguing and may be a reflection of the later expansion of the taxon within the catchment (see 10.2.1). Alternatively the record could provide evidence of local variation in response to regional climatic change, although why is uncertain as the site locations and topographies are all broadly similar.

Environmental conditions during the proposed PBO favoured a return to vegetation characteristic of the start of the Holocene, with open *Betula* woodland dominant and damp grassland and tall herb communities common. Analysis of *Betula* pollen grain size provided no evidence for the presence of *B. nana* (dwarf birch) and it is unlikely that the taxon re-expanded within central Holderness. A similar lack of dwarf birch is seen in a record from the Lomond Hills, Fife (Edwards and Whittington, 1997). At Sproatley Bog and Cess Dell it is likely that the decline in hazel was either almost complete or complete (although this is less clear at The Bog at Roos). Changes in the aquatic flora are more variable with *Nuphar lutea* and *Nymphaea alba* increasing at Sproatley Bog, but unchanged at the other sites and *Typha latifolia* declining at both Cess Dell and The Bog at Roos. Whether these responses are related to changing nutrient status, water-levels or temperature is uncertain and little more can be said. It is likely that the shift to climatic conditions unfavourable for the growth of hazel occurred very rapidly, with the complete decline of the taxon occurring within 1 cm at Sproatley Bog. Although it is not possible to assign an exact duration to this decline it is likely that it occurred within *ca* 5-20 ^{14}C years. The above data show that the pollen record can provide a highly sensitive indicator of climate change (see also Edwards and Whittington, 1997).

The changes in vegetation summarised above are consistent with the suggestion of Björck *et al.* (1997) that the European climate was cool and humid during the PBO. It appears that conditions preventing the growth of *Corylus avellana* did not persist for long and it is unlikely that the taxon was absent for the entirety of the proposed 100-150 calendar year duration of the event (*ibid*). This may suggest that environmental conditions were not uniformly severe in central Holderness throughout the PBO. The rapid re-expansion of hazel following its decline suggests that soils were not adversely affected. Although only one other pollen diagram from Holderness shows a possible contraction within the early part of the *Corylus avellana*-type rise (Skipsea Withow Mere; Blackham and Flenley, 1984), the lack of any obvious change in other published diagrams may be a result of the low sampling resolutions employed. The changes in climatic conditions and vegetation composition during the PBO are likely to have had wide ranging effects on human populations living within Holderness, both in terms of food and material resource availability and seasonal activity patterns.

The above data join a growing body of palaeoenvironmental evidence for the effects of Early Holocene climatic fluctuation on the vegetational development of Britain. Other records are available from eastern Scotland (e.g. Whittington *et al.*, 1996; Edwards and Whittington, 1997), western Scotland and the Inner Hebrides (Lowe *et al.*, 1994; Sugden, 2000). It seems likely that when more widespread detailed investigations are undertaken this list will increase to cover much of the British Isles. Whilst it is unsurprising that the vegetation of marginal environments in northern and upland areas of Scotland and the Inner Hebrides will have been prone to the effects of climate change, the data from central Holderness indicate that the lowland vegetation of eastern England was also susceptible. It is likely that the severity of the vegetation change in Holderness at least in part reflects the exposed nature of the North Sea Basin at the time, with Holderness forming part of a vast low-lying plain stretching across to the present day continental mainland (see section 2.5). The climate is thus likely to have been comparatively more continental than at present prior to the loss of the land bridge sometime around 8000-7000 BP.

Consideration of climatic conditions during the earliest Holocene may help to explain the depositional hiatuses that occur between the Late-Glacial and Holocene deposits in several sites in northern Holderness (e.g. Gransmoor, Walker *et al.*, 1993 and Skipsea Withow Mere, Gilbertson, 1984). A marked drop in lake-levels has been observed at the Younger Dryas/Holocene boundary at a number of sites in Britain and mainland Europe (e.g. Harrison *et al.*, 1993; Lowe, 1993; Björck *et al.*, 1997). In some areas of mainland Europe (e.g. The Netherlands; Bohncke and Wijmstra, 1988) lake levels then rise, before dropping again towards the end of the Pre-Boreal (e.g. Digerfeldt, 1988). It is possible that the rise in lake levels was the result of cool, humid conditions during the PBO (Björck *et al.*, 1997). In the context of Holderness, the depositional hiatuses discussed above are likely to result from climatically-induced drops in the local water table at the start of the Holocene. At Skipsea Withow Mere Holocene sedimentation begins at approximately 9880±60 BP (SRR-1944), although this date may be slightly old. It is possible that this was the result of wetter conditions during the PBO, but conclusions must remain tentative and other factors may have been responsible for the increase in the local water table.

(ii) The *Alnus glutinosa* rise

Recent research has shown that a widespread climatic reversal occurred within the northern hemisphere between *ca* 8400 cal BP and 8000 cal BP, peaking at *ca* 8250 cal BP (*ca* 7500 BP; Alley *et al.*, 1997; Klitgard-Kristensen *et al.*, 1998; Barber *et al.*, 1999; Hu *et al.*, 1999). Data from the GISP2 Greenland ice core suggest that the climate was similar to that of the Younger Dryas, being cool, dry and possibly windy, but not as extreme (Alley *et al.*, 1997). The extent to which this event influenced the vegetational development of Britain is largely unknown, although palynological changes that may be linked to climatic deterioration at a broadly similar time have been identified from the Inner Hebrides (Sugden, 2000). It is possible that the effects of the climatic shift may be visible in the pollen records from central Holderness.

A number of wider ecological processes were occurring within central Holderness at the time of the proposed climatic deterioration (e.g. the local expansions of *Alnus glutinosa* and *Tilia* within the catchment of Cess Dell) and separating the effects of these ecological interactions from climate is not easy. At Gilderson Marr *Corylus avellana* influx declines between *ca* 7570 and 7230 BP, dates which coincide with those for the cooling event observed in the GISP2 ice core. The influxes of the other taxa remain unchanged and there is nothing to suggest that the apparent reduction in the *Corylus* population was due to competitive displacement (see section 7.5). A decline in hazel is also seen at Cess Dell between *ca* 7800 and *ca* 7060 BP, with the taxon increasing again after this date. Calibration of these dates gives an age range of *ca* 8600-7870 cal BP which is again in broad agreement with the dates of the cooling event. The decreased hazel influx at Cess Dell coincides with the major expansions of *Alnus glutinosa* and *Tilia,* however, and it is possible that the decline is related to ecological changes associated with these expansions (see below). *Corylus* influx recovers after 7060 BP despite *Alnus glutinosa* and *Tilia* influxes remaining high and competitive exclusion by these taxa cannot explain the initial drop.

A similar decline and recovery of *Corylus avellana*-type (in both percentage and absolute terms) is seen at broadly equivalent times in the records from a number of other sites in eastern England including Star Carr (Dark, 1998b), Hockham Mere, Norfolk (Bennett, 1983b) and Stow Bedon, Norfolk (Bennett, 1986). At the latter two sites, *Alnus glutinosa* is present at low levels throughout, with major expansion only occurring after hazel levels had recovered, whilst at Star Carr the decline in hazel occurs during the major expansion of alder. Despite the data from the GISP2 ice core suggesting that the event was cool (a maximum of 6±2 °C cooler at 8200 cal BP) and dry (Alley *et al.,* 1997), the fact that alder expanded within the timespan of the event at Star Carr and Cess Dell suggests that increased wetness occurred, at least locally, within eastern Yorkshire.

Whilst it is tempting to infer a climatic cause for the declines and recoveries in *Corylus avellana* discussed above, a number of pollen records from eastern England provide conflicting evidence. Several sites show similar fluctuations in *Corylus avellana*-type pollen during the alder rise, but at dates that lie well outside of the range of the cooling event (e.g. The Bog at Roos [*ca* 7180-6670 BP], Gilderson Marr [*ca* 7220-6080 BP] and Saham Mere, Norfolk [from *ca* 6600 BP; Bennett, 1988]). It is possible that the dates suggested for The Bog at Roos are inaccurate, but this is unlikely to hold for the other sites. This questions the suggestion that the changes in hazel levels discussed above (excluding Gilderson Marr) may have been climatically-induced, and it is perhaps just coincidence that they occur at the same time as the proposed climatic deterioration. A decline and recovery in hazel thus seems to be associated with the expansion of alder within lowland eastern England. What is interesting is that it seems to have occurred at varying times with respect to the alder rise depending upon the site (i.e. immediately prior to, during or after sustained expansion). This strongly suggests that the changes were not solely related to competitive interactions between alder and hazel. At Cess Dell and Gilderson Marr, *Betula* increased coincident with the changes, the taxon perhaps replacing hazel as a result of increased disturbance or damper soil conditions, but at other sites *Betula* concentrations remained unchanged. The cause(s) of the hazel fluctuations thus remain uncertain.

As a summary, there is little conclusive evidence for climatic deterioration at *ca* 8200 cal BP, particularly when compared to the clarity of the vegetation changes within the inferred Pre-Boreal Oscillation. Whilst it is possible that the decline in hazel influx at Gilderson Marr may be related to a climatic shift, the data are unclear and natural ecological processes could also be responsible. It is likely that the decline and recovery in hazel observed at a number of other sites is related to ecological conditions around the time of the alder rise and not directly linked to climate. More secure conclusions would require further investigation, preferably supplemented by an independent record of climate change.

10.3 The role of humans in shaping the Holocene landscapes of central Holderness

This section reviews the evidence for human activity within the palaeoecological records obtained for this thesis and discusses key points relating to the detection of anthropogenic effects within the pollen and charcoal records. Summaries of the evidence for human activity in the site records are provided in Tables 10.9 and 10.10, and the charcoal records from the sites are presented in Figures 10.1 and 10.2.

10.3.1 Evidence for human activity in the new palaeoenvironmental records

(i) The Upper Palaeolithic and Mesolithic; *ca* pre-10,200-5500 BP (*ca* pre-11,520-6310 cal BP)

There is no evidence for human activity during the Younger Dryas within the pollen or charcoal records from Sproatley Bog. There is a similar lack of clear evidence for Early Mesolithic human impact in the records from Cess Dell, Gilderson Marr and The Bog at Roos (Table 10.9). It is possible though that the reduced *Corylus avellana* influx, high charcoal frequencies and erosion during SB-3(d) reflect the activity of Early Mesolithic peoples close to the shores of Sproatley Bog between *ca* 9290±70 BP (AA-30882) and *ca* 8975±75 BP (AA-30883). The presence of three clearly defined reductions in hazel, each associated with high charcoal input and separated by periods of partial woodland regeneration suggests that disturbance was most intense between *ca* 9290-9240 BP, 9180-9130 BP and 9070-9030 BP (assuming the accuracy of the radiocarbon dates). It seems unlikely that fire was used to create the initial clearing(s), although burning may have been employed to maintain open areas (see section 8.5). Any purposive burning was clearly not aimed at encouraging hazel growth. It cannot be ascertained from the available data whether the area was occupied year-round or seasonally. Similarly the pollen record could be reflecting regular activity over a number of years, or more sporadic activity every few years. The presence and clarity of the above disturbance/regeneration episodes at such an early date is unusual in British pollen diagrams.

A number of authors have discussed the possibility that increased clearance may have occurred during the Late Mesolithic in order to raise the productivity of the dense woodland present at the time by favouring browse species (hence attracting game) and berry- and nut-producing taxa (Innes and Simmons, 1988; Simmons *et al.*, 1993). This may have been as a response to the lower productivity of the woodland compared to that of the earlier Mesolithic and/or increasing population pressure (Thorpe, 1999). It would be unwise to generalise for the study area given that only three of the four profiles analysed cover this period, but evidence of potential Late Mesolithic human impact is seen in the records from both Gilderson Marr and Cess Dell. Whilst the data from Cess Dell are unclear and could feasibly be reflecting predominately natural processes, such as a rising local water table (CD-6; see section 6.5), it is likely that the increased disturbance seen in the record from Gilderson Marr during GM-5 (*ca* 7200-6005 BP) was at least partly human in origin (section 7.5). Charcoal particles are frequent but variable during the zone and closely follow the *Calluna vulgaris* curve. This suggests that fire frequency was linked to the availability of a flammable vegetation type (i.e. heathland; section 7.5). It has been proposed that fire may have been used as a direct clearance agent by Mesolithic peoples (e.g. Mellars, 1976; Edwards, 1990; Innes, 1990). Conversely, Simmons and Innes (1996a) present data indicating that although fire may have been used to maintain open areas on the North York Moors during the later Mesolithic, it was not used to produce the initial clearings. Whether fire was used for clearance at Gilderson Marr between *ca* 7200 BP and *ca* 6005 BP (GM-5) is unclear and perhaps unlikely given the probability that the bulk of the catchment vegetation would have been of low flammability (cf. Rackham, 1988; Peterken, 1996; Brown, 1997b). The record more likely reflects charcoal inputs from the burning of felled wood (e.g. used in campfires) and perhaps also areas of open vegetation including heath.

(ii) The Neolithic, Bronze and Iron Ages; *ca* 5500-1930 BP (*ca* 6310-1890 cal BP)

The records from Gilderson Marr and The Bog at Roos both show prolonged periods of potentially Early Neolithic disturbance in post-elm decline deposits (Table 10.10 and sections 7.5 and 9.5). At Gilderson Marr, a period of reduced woodland cover, increased run-off and high erosion occurred between *ca* 5430 BP and *ca* 4190 BP (although the initial date may be too old; Figure 7.15). Disturbance of the woodland canopy and increased run-off also occurred at The Bog at Roos during RBO-5 (perhaps between *ca* 4790 BP and 4390 BP; Figure 9.16). Interestingly, large Poaceae pollen grains are consistently present at both sites during these periods. The problems of separating the pollen of wild from cultivated Poaceae highlighted in chapter 5 mean that conclusions must remain tentative, but it is possible that cereals were grown within both catchments. If this was the case, then this suggests that arable cultivation was initiated within central Holderness during the Early Neolithic. The longevity of the inferred disturbances suggests that permanent settlements are likely to have existed close to both catchments, particularly if the large Poaceae pollen grains reflect arable cultivation. Although dating is insecure in the profile from The Bog at Roos, it appears that there is considerable overlap between the times of the above disturbance phases. Given that the two sites are located approximately 4 km apart, it is likely that the data are reflecting the activity of two separate, coexisting communities within central Holderness.

Simmons *et al.* (1993) suggest that there is evidence for a reduction in clearance activity in areas of the North York Moors at the transition from the Early to Late Neolithic, with woodland regeneration occurring and less intense land-use inferred. Although the data for these time periods is limited in central Holderness, less intense (but continued) activity appears to have occurred within the catchment of The Bog at Roos during the later Neolithic. There is no evidence for changing land-use across the transition from the Early to Late Neolithic at Gilderson Marr though, with high levels of disturbance continuing until *ca* 4190 BP when the record ends.

A lack of woodland regeneration following canopy disturbance is a distinctive feature of many Neolithic and Early Bronze Age pollen diagrams (Brown, 1997b). Although dating controls are poor, this appears to hold for the later Neolithic and earliest Bronze

Age record from The Bog at Roos. It is likely that clearance intensity increased from *ca* 3700 BP, although the presence of a depositional hiatus means that it is not possible to directly date the onset of sustained deforestation. It is clear though that the catchment of The Bog at Roos contained little or no woodland by the start of the Iron Age (*ca* 2660±50 BP [AA-32296]), suggesting that clearance occurred during the Late (or perhaps Mid-) Bronze Age. This is similar to other dates for the onset of major, sustained woodland clearance within lowland Britain (e.g. Bell and Walker, 1995; Roberts, 1995). The low arboreal pollen input during the Iron Age section of the profile indicates that sustained human activity occurred within the catchment throughout the period, and it is likely that the high charcoal levels predominately reflect anthropogenic burning. Low levels of large Poaceae pollen may indicate the occurrence of arable agriculture and it is likely that at least part of the Poaceae undiff. and grassland herb input reflects the presence of meadow and/or pasture.

(iii) The Roman and Historical Periods; *ca* 1930-0 BP (*ca* 1890-0 cal BP)

The Roman and Historical Periods are covered by the profile from The Bog at Roos, with the Early Anglo-Saxon Period also represented at Sproatley Bog. Although there is evidence for change within the open ground flora (notably variation in the extent or location of grassland) through time at The Bog at Roos (section 9.5), the arboreal record during the Roman and Historical Periods is broadly similar to that of the Iron Age, and there is nothing to suggest that woodland ever recovered to significant levels within the catchment. The open nature of the vegetational environment is suggestive of continual human activity from the Roman Period until the present day. This is supported by the consistently high levels of charcoal, which presumably primarily reflect anthropogenic burning (Figure 10.2). As was the case for the preceding Iron Age, it is likely that a large proportion of the grassland pollen reflects the presence of pasture/meadow, whilst the consistently low levels of large Poaceae pollen (including *Secale cereale*-type) may indicate that cultivation of cereals occurred close to the site. A similarly open landscape is indicated by the Anglo-Saxon record from Sproatley Bog, although the area surrounding the site appears to have been more intensively cultivated (see section 8.5). The data suggest that *Secale cereale* (rye), other cereals, *Linum usitatissimum* (flax) and *Cannabis sativa* (hemp) were cultivated locally. Hemp was also grown at low levels within the catchment of The Bog at Roos from *ca* 1030 BP until 230 BP (*ca* AD 1000-AD 1770).

The palynological data for the later historical period compare favourably with the documentary evidence, which indicates that the landscape of central and eastern Holderness was almost entirely open and heavily farmed (e.g. Strickland, 1812; Harris, 1959; Woodward, 1985). For example, Strickland (1812) notes that only two areas of woodland occurred in eastern Holderness during the early part of the nineteenth century, and that very few hedgerow trees were large enough to provide timber. Further insight into the nature of the landscape during the nineteenth century is provided by Head (1835, in Woodward, 1985), who comments upon the large sizes of the fields:

"there can be no finer picture of an arable district; spacious fields, consisting of fifty, sixty, and as far as eighty acres, fenced by lofty, solid, impenetrable quick hedges..."

Whilst Harris (1959) notes that prior to enclosure (before *ca* AD 1700):

"The winds had almost free play over this type of country, for there were few internal hedges, walls or windbreaks outside the villages to hinder their progress. This was a very austere countryside".

The palynological data suggest that a similarly windswept and managed landscape may have existed since at least the Iron Age, with wood for fuel and timber likely to have been scarce.

(iv) Summary

If it is accepted that the episodes of vegetational disturbance discussed above result (at least in part) from human activity, then the pollen (and charcoal) records obtained in this study can be used with care to supplement the poor archaeological record for central Holderness by suggesting the timings, durations, character and approximate locations of any anthropogenic impacts (cf. Edwards, 1979, 1991, 1998). The palynological record suggests that there has been significant landscape-scale clearance activity, at least intermittently, within central Holderness during all cultural periods since the Early Mesolithic. Disturbance appears to have increased in intensity and frequency after, or possibly during, the Late Mesolithic. The observation of Dinnin (1995) - that there is no evidence within the pollen record from Holderness for the effects of humans prior to *ca* 5000 BP - can thus be refined. It is likely that the absence of clear evidence in previous studies was largely a consequence of the low sampling resolutions that were employed. It can also be suggested that the poor archaeological record for the area reflects the burial or loss of sites rather than a low level of human activity *per se.*

There appears to have been no set pattern in the combinations of arboreal taxa that were reduced during disturbance phases in the Mesolithic and Neolithic, with varying combinations of *Corylus avellana, Ulmus, Quercus* and perhaps *Tilia* (see Tables 10.9 and 10.10). A common feature of the periods of increased disturbance is that *Corylus avellana* does not appear to have expanded as a result, which is perhaps surprising given that hazel is a light-demanding taxon and would be expected to benefit from decreased canopy density (Grime *et al.,* 1988; Peterken, 1996; Brown, 1997b). The observation that the taxon apparently declined during four of the six pre-Bronze Age disturbance episodes recorded in this study (Tables 10.9 and 10.10) suggests that hazel populations may have been reduced by human activity, rather than favoured as on the North York Moors (Innes and Simmons, 1988; Innes, 1990).

The problems of separating wild from cultivated Poaceae pollen mean that conclusions relating to the occurrence of cereal cultivation are tentative (see section 10.3.2). It seems unlikely though that the clay-based soils of Holderness were unattractive to early farming as suggested by Beckett (1975), who argued that significant arable activity did not occur within the area prior to the Anglo-Saxon (Early Medieval) Period.

10.3.2 Detecting human activity in the pollen and charcoal records in this study: conclusions and major issues

(i) Detecting arable agriculture in the pollen record

The results of the investigations in chapter 5 suggest that some wild grasses have pollen that is indistinguishable from that of *Avena, Triticum, Hordeum* and possibly *Secale cereale* using the keys of Andersen (1979) and Küster (1988). This presents a serious problem in Holderness, where the absence of macrofossil evidence from prehistoric contexts means that conclusions concerning the role of arable agriculture are based solely upon the pollen record.

Assessment of whether the data are indicating arable cultivation or input from wild taxa subsequently needs to be based upon consideration of the wider palaeoecological record, an approach which is hampered by a number of problems. Firstly, the association of cereal-type pollen with taxa that can occur on arable land encourages the data to be interpreted as reflecting arable activity (Edwards, 1988). This is not necessarily the case, with very few taxa occurring solely as weeds of cereal crops. Secondly, human disturbance activity (e.g. woodland clearance) may encourage the expansion of grasses associated with disturbed ground (Edwards and Hirons, 1984) and the woodland edge (e.g. *Elymus caninus,* a species included within the Cerealia-type of Küster [1988]). A reduction in woodland cover will also promote the longer distance transport of existing Poaceae pollen populations by decreasing the level of filtration (Edwards, 1993). Increased run-off as a result of deforestation may also favour wetland grasses producing large pollen. The above observations mean that the presence of cereal-type pollen in association with inferred anthropogenic disturbance activity does not implicitly indicate the occurrence of cereal cultivation. Interpretation of whether cereal-type pollen indicates growth of domesticated Poaceae thus depends at present upon personal interpretation of the entire palaeoecological record (i.e. the weight of evidence; Edwards and Hirons, 1984), which is far from ideal. Conclusions must also be carefully qualified (Edwards, 1989).

Associated with the onset of arable farming is the phenomenon of early cereal-type pollen. A number of sites have yielded grains dating <1000 yr prior to the elm decline, an event traditionally taken as a marker horizon for the onset of arable cultivation within the British Isles (e.g. Williams, 1985; Innes, 1990; Molloy and O'Connell, 1987; O'Connell, 1987; Edwards and McIntosh, 1988; Wiltshire and Edwards, 1993). This has led to the tentative suggestion that the data are reflecting the occurrence of early agriculture (Edwards and Hirons, 1984; Edwards, 1998).

A total of 10 large Poaceae grains in deposits dated to between *ca* 6110 BP and 5660 BP were found at Cess Dell and Gilderson Marr (Tables 5.3 and 5.4). In addition, a *Hordeum* group/Small Poaceae-type grain dated *ca* 5360 BP was located in the profile from The Bog at Roos. This date is very close to that of the elm decline within the catchment, however (dated as 5290±90 BP AA-32293), and falls within the age range suggested by Spratt (1993a) for the Neolithic Period in northeast Yorkshire (Appendix 1). The majority of the above grains (9 out of 11) were located in the profile from Cess Dell and were associated with a period of woodland decline, possibly resulting from human clearance activity. Despite this, on the basis of the discussion in section 6.5 it is felt most likely that the grains originate from wild grasses (possibly wetland taxa). The single grains from Gilderson Marr and The Bog at Roos may similarly reflect incidences of undomesticated species. If this is the case, then there is no clear evidence for the occurrence of pioneer Neolithic cultivation prior to the elm decline within the study area. Alternatively, the above grains could indicate early woodland-based cultivation, but frustratingly this cannot be proven on the basis of the available data and it would certainly be unwise to infer agriculture solely on the basis of the large grass pollen record. As Edwards (1998, p.73) states:

> "Ultimately, proof of such early agriculture may need to come from excavation and/or macrofossils, assuming that the dating evidence is also secure."

Two discrete groups of large Poaceae pollen, containing grains inseparable from those of cereals, were also found in the earlier Holocene records from central Holderness (groups 1 [*ca* 10,100-9600 BP] and 2 [*ca* 8050-6800 BP] of chapter 5). Given the ages of these groups it is highly unlikely that the grains originate from cultivated taxa, with ecological conditions clearly favouring the growth of one or more wild species capable of producing cereal-type pollen during these periods. Other cereal-type pollen grains dated *ca* 7500 BP and 6900 BP have been found in profiles from Connemara, western Ireland (O'Connell, 1987). Like the group 2 grains of this study they were associated with the initial local expansion of *Alnus glutinosa* and it may be that as more profiles are examined in detail from across Britain, other cereal-type pollen grains are found coincident with this event. The presence of these two groups within the study area re-emphasises the possibility that the cluster of grains dating <1000 years prior to the elm decline may also originate from wild taxa. Although care should be taken in extrapolating the data to regions beyond the study area, this may also apply to the pre-elm decline grains located elsewhere in Britain. Whilst perhaps unlikely given that grains of this age have been found across the British Isles in differing environments, the possibility remains.

(ii) Interpretation of the charcoal record

In this study emphasis was placed on the presence of sustained charcoal levels as an indicator of human activity, particularly during the Mesolithic and Neolithic Periods. The fact that prehistoric peoples utilised and controlled fire is not in doubt, what is of key significance to the interpretation of the charcoal record is the importance of natural fire within central Holderness during the Holocene. It seems theoretically unlikely that the broad-leaved woodland that dominated the region during the Early-Mid Holocene would have been particularly flammable (Rackham, 1988; Peterken, 1996; Brown, 1997b). As a result, it may be expected that any naturally occurring fire within the dryland vegetation (presumably caused by lightning) would have been of low intensity and limited spatial extent and would have produced little charcoal.

Support for these suggestions is provided by the charcoal records from the study sites. The combination of four records from similar site types within a constrained area allows a detailed fire history to be reconstructed and strengthens interpretation. The high charcoal levels at all sites during the earliest Holocene (Figure 10.1) are likely to largely reflect erosional inwash of fragments, although it is possible that limited burning of the open *Betula* woodland also occurred. With the exception of several periods of high input that are generally site-specific, charcoal levels then drop to become low from *ca* 9500-9400 BP (approximately the beginning of the initial *Corylus avellana* maximum) until *ca* 5500 BP. Although the data are more limited, a similar pattern is seen during the Neolithic (*ca* 5500-3700 BP; Figure 10.2). This suggests that burning (however caused) was infrequent or absent within the site catchments for much of the Mesolithic and Neolithic Periods.

Of interest are the periods of sustained moderate to high charcoal input seen at differing times within the sites. These primarily coincide with prolonged periods of canopy disturbance with the exception of Gilderson Marr, where although charcoal inputs are high between *ca* 8020 and 6780 BP, visible woodland disturbance only occurs from *ca* 7200 BP. During this period, the charcoal to pollen ratios closely follow the *Calluna vulgaris* curve. Even given the presence of a combustible vegetation type (e.g. heathland in the above example from Gilderson Marr), an extremely high lightning return frequency would be required in order to account for these prolonged charcoal peaks by a natural mechanism. Given the similarities in location, topography and dominant vegetation types between sites, it also seems unlikely that repeated natural fires would have occurred within one catchment, yet have been infrequent or absent at a similar time within the rest of the study area. This suggests a human as opposed to natural origin for the periods of high charcoal input (cf. Edwards, 1996).

This raises the possibility that the charcoal record may provide a proxy indicator of human activity within central Holderness, although other factors including inwashing of particles also need to be taken into account. This latter point is exemplified by the extremely high earliest Holocene charcoal levels at all sites (discussed above) and also by the moderate inputs of charcoal at Gilderson Marr between *ca* 9270 and 9100 BP, which are again associated with reduced LOI values and similarly interpreted as resulting from erosional inwash of reworked particles.

The frequent correspondence between high charcoal levels and sustained periods of woodland disturbance (interpreted as possibly anthropogenic in origin on the basis of the pollen and erosion records; see e.g. sections 7.5 and 8.5) is clear. This does not imply that fire was used as a direct clearance agent (see section 10.3.1). Similarly high charcoal levels are seen during the later prehistoric and historical periods (Figure 10.2) when there is considerable evidence for sustained clearance and the active maintenance of open areas. It is interesting to consider whether the charcoal record can be used to infer a human presence in the absence of visible disturbance in the pollen record (cf. Day, 1995). This is possibly the case at Gilderson Marr between *ca* 8020 and 7200 BP where the high levels of burning are most feasibly interpreted as primarily anthropogenic in origin (see above). It is more difficult to interpret the low charcoal levels seen throughout much of the Early-Mid Holocene though, as the fragments could originate from occasional natural fires, long-distance transport of particles or low levels of anthropogenic burning (e.g. camp fires; Bennett *et al.*, 1990).

A final point relating to the interpretation of the charcoal record is that of the reduction in charcoal input which has been observed approximately coincident with the elm decline at a number of sites in Britain (Edwards, 1988, 1990, 1998; Bennett *et al.*, 1990; Simmons 1996). It has been tentatively suggested that declining charcoal frequencies at this time could provide a proxy indicator for the transition from a Mesolithic to Neolithic economy (Edwards, 1998). The drop in charcoal receipt may reflect changing burning practice and/or a shift in settlement location (Edwards, 1998), with sites typically located further from lakes during the Neolithic than the Mesolithic (*ibid*). For example Bennett *et al.* (1990) observe that in East Anglia, Mesolithic camps were frequently located close to lake edges, whereas Neolithic settlement sites were situated on upland areas distant from basins, where conditions were more suitable for agriculture and the elevation provided commanding views. The authors argue that the drop in charcoal input after *ca* 5000 BP at Hockham Mere, Norfolk resulted from a reduction in the number of particles reaching the basin due to the greater distance between charcoal sources and the sampling site.

The data obtained from Gilderson Marr and The Bog at Roos allow these ideas to be assessed in the context of the Mesolithic-Neolithic transition in eastern Yorkshire. There are clear differences in the charcoal records from Gilderson Marr and The Bog at Roos around the time of the elm decline. At Gilderson Marr there is no obvious drop in charcoal input (Figure 7.15), with charcoal to pollen ratios high for considerable periods both before and after the elm decline. It is likely that the bulk of the input reflects the activity of humans (see section 7.5). Whilst the possibility that the record between *ca* 5930 and 5445±75 BP (AA-32310) reflects the actions of pioneer Neolithic peoples cannot be totally discounted, there is little evidence for this and it seems far more likely to result from Late Mesolithic activity. From *ca* 5445±75 BP (AA-32310) considerable inferred Early Neolithic disturbance of the dryland vegetation is indicated along with significant soil erosion and possibly arable cultivation (section 7.5). Despite the palynological evidence for changing land-use, charcoal levels are relatively constant. It is likely that the sustained charcoal inputs indicate that burning remained frequent and in a similar location during the Late Mesolithic and Early Neolithic Periods, and it is not possible to detect a change in burning form or regime.

If the pollen and charcoal data are indeed reflecting both Late Mesolithic and Early Neolithic activity close to the basin, then the lack of an obvious shift in activity area (cf. East Anglia; Bennett *et al.*, 1990) can perhaps be explained by consideration of the topography of central Holderness. The subdued, undulating relief means that the distinction between 'upland' and 'lowland' areas is not as obvious as in many other areas of Britain. For example the slopes around Gilderson Marr would have been comparatively well-drained and presumably have provided one of the most suitable areas in the region for both settlement and agriculture. The archaeological record supports the suggestion that similar areas were exploited by both later Mesolithic and Early Neolithic cultures, with finds concentrated around bodies of freshwater and valley sides during both periods (see section 2.4.1).

Conversely at The Bog at Roos, although charcoal input is very low prior to the elm decline, fragments become consistently less frequent shortly after the event (Figure 9.16), which potentially supports the hypothesis that activity areas and/or burning regimes changed at the onset of the Neolithic period (although it should be remembered that the start of the Neolithic in Holderness is unlikely to have coincided with the elm decline). Interpretation of the record is difficult, with the low levels of charcoal fragments perhaps reflecting variation in natural or anthropogenic burning within the catchment or in the wider region, depending upon whether they derive from local sources or result from long-distance transport (thus representing the regional 'background rain'). Unlike Gilderson Marr, there is little evidence for significant human activity close to the site during either the Late Mesolithic or earliest Neolithic, which is perhaps of importance in explaining the differences between the charcoal records at the two sites.

Given that appropriate records for the Mesolithic-Neolithic transition are only available from two of the Holderness sites, and that only one of these accords with a charcoal reduction hypothesis, it would be unwise to extrapolate further. Clearer patterns may emerge when more data become available, and the possibility that the charcoal record may shed light on changing settlement patterns and land use during this period remains intriguing.

10.4 Pollen preservation

10.4.1 Synthesis of results

With the exception of two periods during the Early Holocene (discussed below), the pollen preservation records from each site do not show obvious regional trends, each record reflecting site-specific depositional and recruitment conditions (see Figures 6.2, 7.2, 8.2 and 9.2). The first exception to this is the earliest Holocene where broken, crumpled and corroded grains are frequent. This seems to be associated with high levels of erosion and probably reflects the combination of mechanical damage incurred during inwashing, and perhaps the input of pollen from soils, the litter layer and older deposits.

Secondly, type-1 corrosion levels are increased at Cess Dell between *ca* 9440 and 8040 BP (CDDET-C), at Gilderson Marr between *ca* 9390 and 8400 BP (GMDET-B), and at The Bog at Roos from *ca* 9500 BP until 7600 BP (RBODET-A). As discussed in the relevant results chapters, it is possible that the corrosion was the result of limited stream interaction or increased inwashing from the soil and/or litter layer during these periods. There is significant overlap between the phases of elevated corrosion at the three sites, raising the possibility that the records are reflecting a regional environmental process such as a period of increased wetness. The lack of pollen preservation analyses from lowland eastern England means that comparison with nearby areas is not possible. Data are available from Scotland, however, although there is no evidence of a similar trend (Lowe, 1982; Tipping, 1987b). Tipping (1996) suggests that the period between *ca* 9000 and 8000 BP may have been relatively moist in Britain, but in the absence of secure climatic data for eastern England conclusions remain tentative, and it is possible that some other (perhaps site-specific) factor(s) may have been responsible for the trend of increased corrosion.

Significant levels of corrosion also occur in samples immediately preceding a depositional hiatus (e.g. LDPAZs SBDET-B and RBODET-G). In these instances it is likely that the high corrosion levels reflect post-depositional oxidation of the palynomorphs due to reduced water levels within the basin. At Gilderson Marr, high corrosion levels during GMDET-C are likely to reflect either post-depositional lowering of the water table, or seasonal drying of the deposit during formation. It is likely that *Phragmites australis* stands grew upon much of the basin surface during this zone and Brown (1997a) has suggested that seasonal drying often occurs within areas of shallow reedswamp. Tipping (1987b) suggests that corrosion levels within the Loch Awe Valley were largely controlled by the levels of organic matter either within the basin (particularly peats at the lake edge) or soils within the water catchment. This does not seem to be the case in the study sites, where there is no clear relationship between sediment organic content and corrosion level (excluding the earliest Holocene, discussed above).

Of interest is the observation that two forms of perforation corrosion were noticed during counting (see section 4.3.3.2 and plates 4.1-4.4). Frequencies of the two proposed forms do not appear to be linked (Figures 6.2, 7.2 and 9.2) are there is nothing to suggest that one is merely a more severe form of the other. In combination with the marked size differences between the two types of perforation (plates 4.1 and 4.3), this suggests that they are discrete forms of corrosion. Type 1 corrosion occurs throughout the three profiles in which the corroded grains were split into the two categories (Figures 6.2, 7.2 and 9.2) and is by far the more dominant form. Whilst isolated type 2 corroded grains occur sporadically within each record, consistent levels only occur in LDPAZs GMDET-C, RBODET-G and CDDET-E. In each case drying of the deposit is inferred, with a significant depositional hiatus occurring during RBODET-G.

Although it is unclear how the formation processes for type 1 and type 2 corrosion differ (if at all), separating the two types potentially provides more information than grouping them under the general heading of 'corrosion'. The pattern of exine loss on type 2 corroded grains is suggestive of tunnelling (plate 4.3), but by what is uncertain. The diameters of the scars are broadly similar to those of fungal hyphae and although the frequencies of hyphae within the pollen preparations were not quantified, large numbers of hyphal fragments were evident in samples from within GMDET-C (where type-2 corrosion levels were high). Pollen types susceptible to type 1 corrosion also seem to be susceptible to type 2 corrosion, with the latter form noted most frequently in *Corylus, Betula* and *Alnus,* and occasionally in *Ulmus* and Poaceae undiff. At present no positive conclusions can be made, but it is possible that the proposed forms of perforation reflect two different formation processes, albeit both associated with oxidising conditions. More secure conclusions would require further work.

A consistent pattern within the data is that 'early' grains of the principal arboreal taxa (i.e. preceding their inferred local expansions) are generally deteriorated, with all deterioration forms represented. This shows in the deterioration diagrams as a series of marked spikes (see Figures 7.6 and 7.7 for examples) and is interpreted as reflecting damage incurred during long-distance transport or reworking of pollen, rather than sparse local growth. High levels of deterioration are also seen following the major local decline of a taxon (e.g. *Ulmus*; Figure 9.5) and are interpreted in a similar way.

At Cess Dell and Gilderson Marr, increased levels of deterioration are seen in the topmost sections of the profiles. Both sites are overlain by considerable thicknesses of colluvium and it is likely that the upper deposits would have been susceptible to mechanical compression, bioturbation and drying (due to fluctuations in the local water table) as the colluvium formed upon the peat surface. The data are thus likely to be reflecting the prolonged exposure of the upper deposits at, or close to, the ground surface.

10.4.2 Pollen preservation state as an interpretative tool: an assessment of the approaches employed in this study

Pollen preservation analysis proved to be an extremely useful technique in allowing changing taphonomical relationships (e.g. changes in the dominant forms of inferred recruitment) and the reliability of the pollen record through time to be assessed. The technique also supported the radiocarbon dating programme in detecting several depositional hiatuses within the profiles. Despite this success, several issues mean that interpretation of the pollen preservation record is not straightforward. Although the modes of formation of corroded grains are largely understood (but see above), it is less certain how amorphous, broken and crumpled grains arise (Tipping, 2000). In combination with the likelihood that grains showing each deterioration form could reflect a number of different formation processes and have become incorporated into the record in a variety of ways, this means that it is still largely a matter of personal interpretation as to how the data are explained. It is also likely that a wide number of taphonomic changes will not be visible in the preservation record, with perhaps only the more drastic shifts in modes of recruitment, or within basin characteristics noticeable. This would not necessarily be a bad thing as it is such effects that are most likely to have an influence on the pollen record.

Formal LDPAZs were assigned in this study. This was done primarily to facilitate comparison between the records obtained from the four study sites, but also to simplify interpretation of the pollen record. The assignment of LDPAZs does not provide any additional information, but serves to split the profile into sections displaying similar overall preservation characteristics. Whilst this can be done by eye, in deep profiles with complicated deterioration patterns (e.g. The Bog at Roos, Figure 9.2) it is not easy to summarise the data mentally and clearer trends emerge upon zonation. By comparing LDPAZs with the corresponding LPAZs, the possibility that a change in the pollen record is linked to changing preservation characteristics is easy to explore. For example a period of decreased arboreal representation during GM-3 (Figure 7.10) corresponds closely to the stratigraphical position of GMDET-C (Figure 7.4) which is characterised by high corrosion levels. On the basis of this correspondence it was argued that the drop in arboreal input was likely to be the result of post-depositional pollen loss, rather than real population declines within the catchment (see section 7.4.1.2).

Whilst the approach was very useful in this study, its wider applicability is less certain. In studies where data from a number of sites need to be compared then the approach may be of benefit. Such data can also be assessed successfully by eye without the need for formal zonation (e.g. Lowe, 1982; Tipping, 1987b). The main benefit of the technique may be that it encourages careful consideration of the reliability of the pollen record through time, identifying sources of potential bias within the data and aiding interpretation of the pollen record. The suggestion of Tipping (2000) that preservation analysis should accompany palynological studies as a matter of routine is re-emphasised, with the technique producing considerable information for minimal additional analytical time.

10.5 Project evaluation and suggestions for future work

10.5.1 Project evaluation

This section presents a brief assessment of the success of the project in approaching the questions outlined in section 1.1.2. The results of the pollen preservation analyses have been assessed above.

The principal aim of the study was to produce a detailed reconstruction of the vegetational and wider landscape of central Holderness during the Holocene. By selecting four basins with relatively small catchment areas, four non-overlapping (spatially) records of vegetation, fire and erosion history were produced. This allowed the assessment of local variation in vegetation composition through time within the area. Coverage of the Early-Mid Holocene was good, although the later Holocene was only covered by the records from The Bog at Roos and Sproatley Bog. The radiocarbon dating programme provided absolute dates for all major vegetation changes (including the initial expansions of the principle arboreal taxa) and all but one of the RPAZs of Beckett (1981).

The application of high resolution sampling (every 1-4 cm) produced far more ecological information than previous studies within the area and highlighted a number of events within the profile from The Bog at Roos that were not detected by the lower sampling resolution employed by Beckett (1975, 1981). The benefits of the approach outweighed the time-consuming nature of the technique and aided the assessment of the changing roles that climate, ecological interactions and disturbance played in controlling vegetational development.

The other main aim of the study was to assess the evidence for human activity within the records, particularly during the Mesolithic and Neolithic Periods. A number of intervals during which landscape-scale human disturbance may have occurred were identified from the Early Mesolithic until the present day, although coverage of the later

Neolithic onwards in the records obtained was sub-optimal. Unfortunately a depositional hiatus in the record from The Bog at Roos meant that it was not possible to directly date the onset of major, sustained clearance within the catchment, but it was possible to produce an estimate on the basis of dates prior to and after the event. AP:NAP ratios were found to provide a particularly useful semi-quantitative measure of relative tree cover/woodland density within the site catchments (see also Smith, 1996), with periods of canopy disturbance evident from the data. The data obtained may be used with care to supplement the patchy archaeological record of the area by providing information on the spatial extent, longevity, character and location of periods of inferred landscape-scale human disturbance activity.

The investigations into the separation of Cerealia from wild Poaceae pollen were also beneficial and provided a warning against necessarily inferring arable cultivation from any pre- or post-elm decline cereal-type pollen, even when associated with canopy disturbance.

10.5.2 Recommendations for future work

The results of this study have suggested a number of key areas that would benefit from further work. The following section serves to re-emphasise knowledge gaps highlighted elsewhere in this thesis as well as forwarding several previously undiscussed ideas.

(i) Palynology, charcoal quantification and archaeological inference

There is clear need for further palynological research within northern and western Holderness. In particular, the production of well-dated, high temporal resolution pollen and charcoal records would allow comparison with the data from central Holderness. This would enable more confident assessment of the degree of variation in the timings of the initial expansions of the major arboreal taxa within the region. Although the records from The Bog at Roos and Sproatley Bog provide a high level of detail for parts of central Holderness, the later Holocene development of eastern Yorkshire remains poorly known. The identification and analysis of deposits covering the period from the

Late Neolithic onwards would be of benefit in investigating the formation of the open landscape that is visible today. One of the aims of such analyses would be to provide an absolute date for the onset of major, sustained clearance activity and to investigate how the event varied in time, space and character.

The relatively low number of published pollen and charcoal records from lowland England (Edwards, 1998) means that the extent to which any landscape-scale impacts of earlier prehistoric peoples varied in character, timing, duration and location is largely unknown (particularly for the Mesolithic). Numerous other questions remain unanswered. Was woodland structure manipulated during the Late Mesolithic in a similar manner to that described for the higher levels of the North York Moors (Innes, 1990; Simmons *et al.*, 1993; Simmons and Innes, 1996a, 1996b), or did the difference in species composition and the inferred higher canopy density in the lowlands (cf. the uplands) necessitate alternative forms of land management and resource gathering? Why were varying combinations of arboreal taxa reduced during inferred Late Mesolithic and Neolithic disturbance episodes in the records obtained in this study (section 10.3.1)? Do the variations reflect the occurrence of different forms of activity or land management, or are the combinations more random in nature?

The results of this study and that of Bennett *et al.* (1990) suggest that charcoal analysis can provide a powerful tool for investigating changing patterns of human activity in lowland landscapes, but a number of questions again remain concerning interpretation of the record. For example, does the charcoal originate primarily from camp fires (cf. Bennett *et al.*, 1990), or was fire used as a tool to maintain open areas (Simmons and Innes, 1996a) or perhaps even in their creation (although this latter possibility seems unlikely; see e.g. section 7.5)?

There is consequently need for the production of further high temporal (and spatial) resolution pollen and charcoal studies from England, aimed at investigating the detection of human impact in lowland environments. Only when more records become available can generalisations concerning spatial and temporal patterns of Mesolithic (and Neolithic) vegetational disturbance and burning regime be made (as has previously been attempted for The North York Moors [Simmons *et al.*, 1993] and Scotland [e.g. Edwards and Ralston, 1984; Edwards, 1989; Tipping 1996]).

(ii) Identification of Cerealia pollen

The investigations into the usefulness of present techniques in separating cultivated from wild Poaceae pollen highlighted a number of difficulties, but suggested that it may be possible to refine the list of potential species for which a grain could originate by combining the attributes used by Andersen (1979) with those used by Küster (1988). Although purely speculative this may provide a fruitful direction of research.

(iii) Holocene climate change

Further investigation into the role that Early Holocene climatic fluctuations played in determining the vegetational development of Britain (and the repercussions for Early Mesolithic cultures) is desirable. At present little is known of the character, number and spatial coverage of the fluctuations within the British Isles, or their influence and expression in the vegetational records from different areas (e.g. the west and east coasts, upland and lowland sites). More specifically there is a need for the production of an independent record of climatic conditions within lowland England during the Holocene. This could be approached via the analysis of Chironomids (to provide a record of lake conditions, including temperature; e.g. Sadler and Jones, 1997) and/or oxygen isotope analysis (if suitable deposits such as calcareous marls exist; cf. Whittington *et al.*, 1996). A multidisciplinary study linking vegetation history with climatic variables would be desirable.

(iv) Pollen preservation analysis

Inferences based upon pollen preservation records are presently hampered by the low number of published reports with which to compare the data, and also a poor understanding of how broken, crumpled and amorphous grains are formed (Tipping, 2000). Further experimental work would be valuable in isolating the causes of these deterioration forms, whilst a greater willingness to include preservation studies alongside standard pollen analyses would increase the database of palaeoecological examples and allow the possibility that regional trends exist to be assessed. Can pollen preservation analysis be used to complement climatic data? For example, can the combination of an increase in both the corroded component and sediment inorganic content (in the absence of any visible vegetation change) be used to infer enhanced inwashing from the soil/litter layer as a result of increased runoff due to a change in climatic regime (e.g. increased precipitation or decreased evapotranspiration)? It would also be interesting to identify whether any differences exist between the modes of formation of the two types of corrosion discussed in section 10.4.1.

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