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Impacts of hunter-gatherers on the vegetation history of the eastern vale of pickering, Yorkshire

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Impacts of Hunter-gatherers on the Vegetation History of the Eastern Vale of Pickering, Yorkshire.

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(Two Volumes)

Volume 1

Submitted in fulfillment of the degree of:
Doctor of Philosophy (PhD),
Department of Geography,
University of Durham,
2003.

University of Durham

Abstract

Research is undertaken into the vegetation and human impact at three previously un-researched archaeological sites from the eastern Vale of Pickering. The vegetation history is reconstructed from the end of the Windermere Interstadial c. 13,000 ^{14}C yr BP until the final Mesolithic c. 5100 ^{14}C yr BP. The early Mesolithic human impact on the vegetation is assessed using a three stage statistical test to establish the internal variability in the data as well as background variations in pollen output.

The results reveal that humans had a small but significant impact on the vegetation around two of the sites. Pollen preservation at the third site precluded analyses of the impacts of humans on the vegetation. The three-stage test used to test for human impact was quite successful but requires revision before any further use. On the whole the tests confirmed the findings of conventional human impact analyses.

During the pre-Holocene fires occurred on a regular basis. These fires varied in location and intensity, suggesting that some of the fires were regional or large-scale, whilst others were small and very localized. A multi-causal explanation has been given for the fires. Later, during the early Mesolithic, human groups are thought to have burnt the reedswamp at the lake edges as part of an economic strategy. Star Carr is the only site that demonstrates clearance of significant areas of woodland.

During the later Mesolithic the hunter-gatherers have a greater impact on the vegetation within the Vale. This is attributed to the need for more resources as a result of vegetation change and increased population levels. Unlike their counter-parts from the North York Moors, the occupants of the lowland Vale of Pickering cause no long-term change to their environment.

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Declaration

No information submitted within this thesis has previously been submitted for a degree in this or any other University.

Statement of Copyright

Acknowledgements

I wish to thank Ian Simmons, Tim Schadla-Hall and Dr Jim Innes for all their support and helpful comments throughout the last eight years.

I have also really appreciated the comments and insights from Ian Shennan, whilst he has been supervising me for the last year.

Lastly to Nikki and Rob, with love, I couldn't have done it without you !

Chapter One – Introduction and Background

1.0 Introduction

1.1 Principal Aim

The principal aim of this study is to investigate the vegetation disturbance and environmental impacts caused by pre-historic hunter-gatherers at three previously un-researched archaeological sites from the eastern Vale of Pickering, Yorkshire, England.

1.2 Background to the Study

The Vale of Pickering is located in north-eastern Yorkshire approximately 8 kms to the south of Scarborough (Figure 1.1). At the end of the last glaciation, the very eastern end of the Vale was the site of a large glacial lake (or lakes), called Lake Flixton. Previously published work has demonstrated that this was a sizeable lake (or lakes) which progressively infilled over the course of the Windermere Interstadial and the Holocene. Following intensive drainage in the 19th and 20th centuries, the lake sediments are now concealed under pasture and arable land.

Research into the archaeological and palaeoenvironmental deposits of the Vale of Pickering were first undertaken by J.G.D. Clark (1954; 1972) and Walker and Godwin (1954), following the discovery of several Mesolithic sites by Moore in the late 40s (Moore 1950, Figure 1.2). The most famous and best excavated of these sites was Star Carr, excavated initially by J.G.D. Clark (1954) and later by Mellars (Mellars and Dark 1998). The site is now acknowledged to be one of the best preserved early Mesolithic sites from North-western Europe. The unparalleled preservation of the finds and the range of wetland archaeological techniques employed, meant that the site yielded a unique amount of information about an under documented period of British prehistory. The Vale of Pickering was also shown to be one of the most important areas in Britain for providing information on the late-glacial and post-glacial environment (Moore 1950; Walker and Godwin 1954).

More than thirty years after the initial excavations at Star Carr the site is still the focus of immense archaeological and palaeoenvironmental interest following the recent excavations by Mellars (Mellars and Dark 1998) and the detailed palaeoenvironmental analyses of Day (1993) and Dark (1998). These latter analyses were able to demonstrate for the first time, that early human groups had a noticeable impact on the vegetation and environment of their surrounding areas.

Excavations over the last 20 years have also shown that the area of the Vale occupied by the hunter-gatherers, was much more extensive than previously envisaged. In addition to the ten sites located by Moore (1950), several other sites have been located and excavated in whole or in part (Figure 1.3; Schadla-Hall 1987a, 1987b, 1988, 1989, 1990; Schadla-Hall and Cloutman 1985; Lane 1998; Lane and Schadla-Hall submitted). Due to the density and variety of sites which have been found within such a relatively small area (Figure 1.3), the Vale is now recognised as being of even greater archaeological significance than before. Consequently, since the 1980s the Vale of Pickering has also been the focus of additional and extensive palaeoenvironmental analyses e.g. Seamer Carr and Flixton Island (Cloutman 1988a; 1988b; Cloutman and Smith 1988; Innes 1994).

1.3 Why do more research in the Vale of Pickering?

Given this dense concentration of palaeoenvironmental work, why is it necessary to undertake more research into the environmental history of the Vale?

Firstly, Star Carr is just one of numerous sites within and around the ancient lake and it is therefore unlikely to be representative of all of them. Many (if not all) of the other sites will have varied in terms of settlement uses, environment, date, duration and intensity of occupation, as has already been indicated by the faunal and lithic remains (Lane 1998). In particular, with the exception of Star Carr, none of the sites have been fully investigated with respect to their impact on the vegetation and environment.

Secondly, the density and variety of archaeological finds have rendered the Vale an area of great archaeological significance. Consequently, detailed investigations into the archaeology and palaeoenvironments around each site will provide an opportunity for an integrated and multi-disciplinary study of the early Mesolithic in Northern England.

Finally, the preservation of organic material has reached a critical threshold within the ancient lake sediments. During the period 1954-1976 no palaeoecological analyses or archaeological excavations were undertaken within the Vale as to some extent the area was considered 'done', despite the limited area that had been excavated. Meanwhile, in the intervening period the intensification of drainage had enabled arable cultivation to be practised on even the deepest peat deposits which has caused extensive damage to some of the early Mesolithic deposits (Schadla-Hall and Cloutman 1985). To illustrate this point, in 1949-50 the deposits at Moore's site 1 (Flixton 1) were completely waterlogged, but by 1986 when the site was re-excavated and the excavations extended, the deposits were no longer wet and the condition of the pollen preserved within the sediments had deteriorated (Lane 1998; Innes 1994). Thus, although it is likely that there were more sites similar to Star Carr around the lake, Star Carr will undoubtedly remain unique in terms of the preservation of its finds and the information they have yielded.

It is in light of this drainage, and the limited amount of time remaining that researchers have started to investigate the eastern end of the lake which until the 1990s had been largely neglected due to the concentration of sites in the Vale as a whole. The present study forms part of this 'rescue' programme of faunal, lithic and palaeoenvironmental analyses which is currently underway. The three sites that form the basis of this study; No Name Hill, Flixton School Field and Barry's Island, were all located at the edge of, or on islands within the former lake and lie approximately 0.8 to 3.4 km to the east and south-east of Star Carr (Figure 1.3).

1.4 Research Questions

This thesis is to present detailed archaeo-botanical investigations into the effect of early Mesolithic hunter-gatherers on the vegetation and environments around these three previously unresearched sites. Using combined pollen, charcoal and sedimentological analyses it should be possible to elucidate the nature of any vegetation/environmental impact, its duration and depending on the presence of macrofossils, the possible season of occurrence. Such research should enable a better understanding of early Mesolithic vegetation exploitation and resource procurement strategies. For instance, is it possible to distinguish differences between the sites and their different functions, from the type of vegetation manipulation alone? Was occupation short-lived or long-term? Did the hunter-gatherers move seasonally or not at all? This study can be viewed as complementary to the analysis of faunal and lithic material from the same sites, which when complete, will allow a much fuller integrated interpretation of the sites and the area as a whole.

This thesis aims to answer the following research questions:

1.   To describe the vegetation history/environment of the area from the end of the last glaciation until the mid Holocene, to place all sites in a broad regional, chronological and vegetational context.

2.   To determine the short-term natural or background variations in pollen output for comparison with the fine resolution pollen studies from selected horizons at the occupation sites.

3.   To assess the degree of local variability in vegetation throughout the study time period.

4.   To assess any differences in the vegetation impact between the Early Mesolithic sites (including Star Carr), and interpret this information in association with the available archaeological data.

5.   To determine the possible presence of pre-Mesolithic cultures in the Vale and any associated impact on their environment.

6.   To identify any differences between Upper Palaeolithic, Early Mesolithic and Later Mesolithic cultures and their effects on, management of and likely attitudes to their environment.

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7. To elucidate the origin of microscopic charcoal found in post Devensian deposits using palaeoecological analyses.

8. To provide further information on the possible links between human occupation and changes in vegetation succession/history throughout the Holocene e.g. the *Corylus* rise, the *Alnus* rise and the *Ulmus* decline; and to investigate any wider issues highlighted by the research.

1.5 Programme of Research

The following section provides a Chapter by Chapter outline of the thesis.

Volume One

Chapter One

The remainder of this chapter, describes the background to the study. This includes the physical setting, geology and formation of Lake Flixton, the current hydrology of the sediments and a brief history of archaeological and palaeoenvironmental research in the Vale. Finally the last section shows the location of the study sites and outlines the reasons behind their selection.

Chapter Two

This chapter outlines the methods of analyses and any assumptions that have been made or problems that had to be overcome, in order to interpret the results e.g. taphonomy and preservation.

Chapter Three

Site analyses commence in Chapter Three with the analysis of the natural vegetation in the Vale. The regional profile taken from the centre of the lake, acts as a control site for later comparison with the profiles from archaeological trenches. The vegetation history of the region is described from the start of the Windermere Interglacial c. 13,000 ^{14}C yr BP until the end of the Mesolithic using the combined methods of pollen, charcoal particle size analysis and direct radiocarbon dating. This allows the new archaeological sites to be placed in their regional chronological and vegetational contexts from this unresearched eastern side of the Lake (Question 1 above). The

vegetation and environment facing the prehistoric settlers is addressed with particular reference to archaeologically documented periods of the early Mesolithic.

At a specific horizon (correlated with a period of early Mesolithic archaeological activity at Star Carr), fine resolution pollen analyses of the regional profile are undertaken. This enables the natural variations in pollen output to be defined for future comparison with archaeologically linked profiles (Question 2). A model is put forward which allows any human impact at the edges to be statistically compared to the regional profile, to isolate any fluctuations caused by human impact versus natural background variations in pollen output.

In addition to providing a backdrop to the human settlement of the area, the regional profile provides a chance to investigate the possible links between human occupation and regional changes in vegetation succession/history, as well as to compare and contrast the vegetation variations within and around the lake from the work already published (e.g. Day 1993, 1996a, 1996b; Cloutman and Smith 1988; Day and Mellars 1994; Questions 3 and 8). It also provides an opportunity to shed more light on some of the issues those papers have raised e.g. pre-Mesolithic burning (Question 5).

Chapters Four to Nine

In these chapters, a total of six selected profiles taken from all three archaeological sites (No Name Hill, Flixton School Field and Barry's Island), are analysed using pollen, charcoal particle size and sedimentological techniques. All sediment profiles were taken within c. 10-30 m of the identified archaeological activity, depending on the preservation status of the sediments. Spatial sampling of this type combined with the analyses from Chapter Three, should fulfil the requirements of anthropogenic palynological studies proposed by Edwards (1982). He stated that: *"Twin requirements for increasing confidence in anthropogenic inferences would be profiles no further than 30m from the woodland edge......with others extending to beyond 300m"* (Edwards 1982:12).

The charcoal record from each pollen profile is then assessed for indications of human or naturally induced fires throughout the whole period and their significance to the

archaeology are discussed. Disturbance phases are detected by the identification of prolonged charcoal peaks in association with changes to the natural vegetation. Fine resolution sampling of 1-2.5 mm sample width is used to investigate periods of small-scale vegetation disturbance within the early Mesolithic environment, at selected horizons from specific cores. Such fine sampling enables time resolutions of c. 1-5 years to be achieved (e.g. Simmons *et al* 1985), dependant on sample thickness and sediment accumulation rates. Such small time period investigations are necessary to determine patterns of disturbance and re-establishment within the vegetation, and to identify the hypothesised 'ephemeral ' occupation of the sites (main research focus).

Each profile is analysed using the statistical model proposed in Chapter Three to attempt to identify periods of human impact on the vegetation. An attempt to explain the processes/strategies which might have caused the vegetation disturbances is briefly made within each chapter (Questions 4 and 7, above), whilst correlation between the three different profiles from No Name Hill is undertaken in Chapter Seven. The results of these palaeoecological analyses should provide information which will also allow the investigation of research questions 3, 4, and 7 to 8 (above).

Chapter Ten

Chapter Ten provides a detailed comparison of the results of vegetation disturbance from the three study sites (main research focus). Within an overview of each archaeological period, all results are interpreted in association with other work from within the Vale and its surrounding areas (e.g. Sections 1.8 to 1.10), including the regional profile and Star Carr. This chapter will mainly concentrate on the overall processes/strategies used by human groups, including differences between the impact at the different sites and within the different archaeological periods (Questions 3, 4, 5, 6 and 7).

Chapter Eleven

This penultimate chapter is used to discuss any wider issues raised by the study (Question 8 above).

Chapter Twelve

This final chapter presents the conclusions of the study.

Volume Two

Figures, tables and pollen diagrams are presented separately in Volume Two.

1.6 Location of the Study Area

1.6.1 Physical setting, geology and hydrology

The Vale of Pickering is a low lying, flat bottomed valley, approximately 7-12 km wide and c. 65 km in length, sandwiched between two upland land areas. To the north, the Jurassic rocks of the North York Moors form a line east-west and are preceded by a dip slope of Corallian limestone. To the south, the gentler chalk escarpment of the Yorkshire Wolds, forms another similar east-west barrier (Figure 1.4).

The basal sediments in the Vale belong to an outcrop of Oxfordian, Kimmeridge and Speeton Clays, that have been heavily modified by glacial activity during the Quaternary (Franks 1996). During the last glacial maximum c. 18,000 ^{14}C yr BP, an ice sheet extended over much of the Vale from the east (Rose 1985), impounding meltwater at the western end in a pro-glacial lake called 'Lake Pickering' (Figure 1.5). After the retreat of the ice sheet at the end of the last Devensian, the impounded water was released and a fairly extensive new lake, Lake Flixton (or series of lakes), was created in the ice scoured depression left at the eastern end of the Vale (Rose 1985; Kendall and Wroot 1924; Catt 1987). The lake was separated from the sea by a low ridge of Quaternary material, probably moraine in origin. Records of the environment and vegetation from within the lake extend back approximately 13,000 ^{14}C yr (Day 1996a), although the earliest dates indicating that the coastal areas of the region were ice free, are dated to 13,042±140 ^{14}C yr BP (Jones 1976a) and 13,045±270 ^{14}C yr BP (Beckett 1981).

The local topography within the eastern vale (east of the A64), is very complex (Kendall and Wroot 1924). The Boulder Clay in the north of the Vale (the Lower

Till series: Franks 1996) was deposited during the westward advance of the glacier from the North Sea during the Dimlington Stadial. On the south side of these clays are sand and gravels known by as the Seamer Carr Sands and Gravels (Franks 1996), which form geomorphically distinct kames and eskers presumably formed beneath and along the edges of the retreating ice sheet. To the north-west of the Lower Till series is a mixed sandy gravel and colluvial deposit (Seamer Gravels), in places overlain by coarse silty sands and sandy clays which are probably of glaciofluvial origin (Franks 1996). The lake was bounded to the west by the sand and gravel deposits of the Supraglacial Sedimentation Complex, which extend past the A64. It was a tapered break in these deposits that allowed an outflow from the lake to flow west within the palaeo-channel of the River Derwent. Figure 1.4 shows a simplified map of the geology of the Vale.

The bed of the ancient lake also had a very varied and complex microtopography. At its maximum Lake Flixton was probably slightly over 4 km in length west to east and greater than 1 km wide in places, with several islands composed of glacial and periglacial deposits (Lane 1998). There were large numbers of streams flowing into Lake Flixton, which may not have had a stable hydrological regime. Not much is known about the dynamics of the lake but the water levels may have fluctuated, especially during the drier summer months. Drainage into the lake would have been north-south from the North York Moors into the River Derwent/lake and south-north from spring lines along the foot of the Wolds escarpment at c. 50 m AOD contour line (Lane 1998).

Over the course of the Windermere Interstadial, the lake gradually infilled with marls and inorganic material, followed by a period when intense solifluction deposits were laid down (the Late Glacial Stadial). This solifluction layer bisects the marl deposits formed during two periods of more temperate climate i.e., the preceding Windermere Interstadial and the succeeding Holocene. This sequence was recognised by Moore as far back as 1950 (Moore 1950). During the Holocene the lake continued to progressively infill with alluvium and peat deposits, with the extent of open water decreasing significantly by 8000 ^{14}C yr BP.

1.6.2 Recent Drainage

Drainage of the lake sediments, which are now concealed under pasture and arable land, has become progressively more intensive since the 19th century, when drainage ditches were cut to reduce seasonal flooding and increase the area under arable. By the 1940s mechanisation allowed the drainage ditches to be deepened, lowering the water table and decreasing the level of the peat deposits. The final lowering of the Hertford cut in the 1970s, combined with deeper drains, has accelerated this peat shrinkage so that in some areas the land level has decreased by more than 2 m (Schadla-Hall 1990). Considering the depth of peat at Star Carr was initially 3 m, peat shrinkage of this magnitude means that many of the archaeological deposits will no longer be waterlogged. This also has implications for the palaeoecological record, as oxidation of the sediments decreases the level of available information retained within the organic record. It is in light of this destruction of the organic record that much of the current work has been undertaken.

1.7 History of Archaeological Excavations in the Vale of Pickering

This section provides a brief history of the archaeological excavations in the Vale of Pickering since the 1940s.

Between 1947-1949 John Moore discovered traces of at least ten early Mesolithic occupation sites within the eastern end of the Vale of Pickering (Moore 1950; Figure 1.2). The vast majority of the lithic finds were still stratified within deep sediments (later dated to the early or later Mesolithic), which had recently been exposed within the sides of a network of drainage ditches within Star and Seamer Carrs. *"By passing my arms into this basal peat it was possible to examine a large area without recourse to excavation"* (Moore 1950:101). From extensive analysis of the geological deposits, Moore concluded that the sediments were a result of sedimentation within a glacial lake and had been interrupted by a period of intense cold (Moore 1950), which we now know as the Late-glacial or Loch Lomond Stadial. Thus sedimentation in the lake spanned a period from the Late Windermere Interstadial to some point in the current post-glacial.

Moore oversaw archaeological excavations at Sites 1 and 2 in Flixton Carr, resulting in the excavation in whole or part, of the two sites now known as Flixton 1 (Moore 1950) and Flixton 2 (Moore 1954). He handed over the excavation of Site 4 (Star Carr) to J.G.D. Clark from the University of Cambridge (Clark 1954, 1972). The key results of these excavations are summarised in Tables 1.1 and 1.2 and referred to in Sections 1.8 and 1.9.

Between 1954 and 1975 after the speedy publication of the Star Carr and Flixton results (Clark 1954; Moore 1950, 1951, 1954), no further archaeological excavations were undertaken in the Vale. This was partly due to the academic view that the area had been 'done' and that Star Carr was a representative site for the European Maglemosian. In contrast to this paucity of field work, Star Carr was still a topic of immense archaeological interest. In 1972 when Clark published a reinterpretation of the site it lead to considerable academic debate, with Clark's own interpretations being challenged by various researchers. Nonetheless, all published work was based solely on reappraisals or reinterpretations of the original data (Table 1.1).

However, in 1974-5 North Yorkshire County Council designated an area of Seamer Carr as the site of a waste disposal facility which would compromise approximately 15 ha of peat deposits. As a result, rescue excavations were carried out between 1976-1985 funded by North Yorkshire County Council and the Archaeology Division of the Department of Environment (now English Heritage). Systematic auguring of the peat along a 10 m grid, in conjunction with initial surface contour surveying, was undertaken in order to establish the sub surface contours of the lake edge and their sediment characteristics (described in Cloutman 1988a). This strategy proved essential for the subsequent location of archaeological test pits and was consequently adopted in all following excavations in the Vale. Systematic test pitting along the shoreline of the former lake identified several sites of various ages (Sites B, C, D, F, K, L, U; see Figure 1.3, Lane 1998), which were excavated in whole or part over the next few years. This renewed archaeological interest within the Vale served to highlight the ongoing destruction of the organic record, caused by intensive drainage since the 1940s and the continuing threat to surviving and as yet undiscovered archaeological material.

As a direct result, in 1985 The Vale of Pickering Research Trust (VPRT) was formed in view of this clear threat to the surviving archaeological material. The aim was to undertake a detailed programme of archaeological excavations around the rest of the former lake, extending progressively towards the east.

One of the Trust's first tasks was to carry out renewed fieldwork at Star Carr. This was primarily because the actual site excavated by Clark (1954) was proposed to represent *'only the water-edge element of a larger site which extended onto the dry land to the north'* (Schadla-Hall 1989:224). These new excavations were carried out between 1985-86 in association with the Department of Plant Science, University College, Cardiff. The excavations were lead by R.T. Schadla-Hall who opened a 13 m trench (Trench A , VP85A), 30 m to the east of Clark's original excavations. These new excavations demonstrated that Star Carr was likely to have covered a much greater area than previously thought and extended onto an eastern promontory (Figure 1.6; Schadla-Hall 1988; Lane 1998).

Additional archaeological fieldwork was also carried out at Star Carr between 1989-1992. This time the work was done by The MacDonald Institute for Archaeological Research and the Department of Archaeology at the University of Cambridge under the direction of Prof. Paul Mellars, described in Mellars and Dark (1998).

Meanwhile, in addition to the recent excavations at Star Carr, the VPRT has also re-excavated Flixton 1 and 2, and partly excavated Moore's Sites 3 (No Name Hill) and Site 6 (Manham Hill). Furthermore, the Trust has located and/or partly excavated five other previously unknown Early Mesolithic sites: VPD, VPE, Flixton School Field, Barry's Island and Flixton School House Farm (see Figure 1.3; Lane 1998), as well as trial pitting and determining the basal contours of over 8 km of the margins of the former lake. Field-walking, excavations and the location of new sites is still an ongoing process for the Trust.

1.8 Archaeological Excavations at Star Carr

This section outlines the key findings from the important site of Star Carr from 1948 to the present. In the past Star Carr has been considered a 'type site' for the European Maglemosian (Pitts 1979), so presentation of the findings from this site will allow the present study sites to be considered within their local and regional contexts. Star Carr is also the only properly researched site from the area, and as such will serve as an important comparison for the study sites.

As outlined in Section 1.7 and 1.8 (above), the main phases of excavation at Star Carr took place between 1949-52 (Clark 1954), 1985-86 (Schadla-Hall 1988) and 1989-92 (Mellars and Dark 1998). However, in the intervening periods, and especially over the last 30 years, the site has been the subject of numerous academic papers. Table 1.1 sets out the key findings from all the excavations and discussions from 1948 onwards. Additional evidence and details are presented in Chapter Ten when the study sites are compared and contrasted with Star Carr.

The main points can be summarised as:

- The extent, range and preservation of artefacts excavated at Star Carr are unparalleled within North-western Europe.
- Occupation occurred on a promontory at the edges of reedswamp about 5 m from open water.
- The site has been interpreted as a hunting stand with some butchery, (Rowley-Conwy 1999). However, the site was used for a wide-range of economic and industrial activities apart from hunting (Dumont 1988, 1989), consequently, the full purpose of the site remains elusive.
- There were two early Mesolithic sites at Star Carr, Clark's site and Trench A, separated by a 'sterile' strip of land. The site at Trench A is earlier than Clark's site and is dated to c. 9650 ^{14}C yr BP.
- The site may have been occupied at some point during all seasons of the year, during the early Mesolithic, although not necessarily by the same human groups or generations.

- There is no evidence to suggest local fishing activities or any other links which may associate the site with the coast, although Mellars and Dark (1998) assume coastal links on 'a priori' grounds.

In-depth descriptions of all the archaeological excavations and their findings can be found in the following publications: Clark (1949, 1950, 1954, 1972), Schadla-Hall (1988), Lane (1998), Mellars and Dark (1998), whilst a list of other related research papers is included within Table 1.1.

1.9 Other Relevant Archaeological Excavations in the eastern Vale of Pickering

This section provides a summary of the remaining (relevant) archaeological sites that have so far been located within the eastern Vale and that date to the Upper Palaeolithic, early Mesolithic or later Mesolithic (Figure 1.3). Numerous other sites have also been located or partly excavated (Lane 1998; Moore 1950), but not all relate to the time periods under consideration. The key findings of this ongoing research are presented in Table 1.2. They can be summarised as:

- Numerous archaeological sites have been identified around Palaeo Lake Flixton. At least twenty Mesolithic or Upper Palaeolithic sites have so far been identified (including Moore's sites). Several additional sites and or artefacts belonging to the Neolithic and Bronze Age have also been found.

- In 2002 at least three open-air Upper Palaeolithic sites have been located within the Vale. This places human groups within the Vale during the Windermere Interglacial and possibly the Late Glacial Stadial. These seasonal and possibly sporadic forays occurred between c. 11,300 –10,200 ^{14}C yr BP, if not earlier (Conneller 1998, 2000b; Schadla-Hall 1987a). The very presence of this Late Upper Palaeolithic material underlies the importance of the Vale for investigating even the earliest human activity after the last glaciation.

- At least three 'Long-blade' activity areas have also been found, suggesting temporary periods of occupation during the Preboreal; a time of rapidly changing climate. Star Carr may also have been temporarily occupied during this time.

- During the early Mesolithic a number of different archaeological sites were located at Seamer Carr. All the sites were occupied at different times, they all had different functions and were located in differing vegetational environments.

- Occupation of the same area at Seamer Carr was intermittent but repeated. Site C and Site K were both occupied during two distinct periods in the early Mesolithic.

- A later Mesolithic arrow-shaft made of Poplar or Willow wood has been found at Site K.

- The water table in the Vale has fallen significantly over the last 50 years. This means that the preservation of early Mesolithic organic remains, particularly undiscovered archaeological artefacts, is under threat.

The information from this palimpsest of archaeological activity will help to place the study sites within a local context and within the local chronology of human occupation within the Vale. Due to the range and variety of sites identified so far, differences between the sites are also crucial to our understanding of the Vale as a whole unit. Key factors which may be of importance are: different site locations and environments i.e., it is interesting to note that the early Mesolithic settlers seemed to deliberately avoid areas of heavy clay (Schadla-Hall and Cloutman 1985); different site functions, identified from faunal and lithic remains; different phases of occupations; the number of occupations at a particular location; use of natural resources; and in the absence of secure dates, the fauna or environment can provide a rough age estimate for a site.

Additional evidence and further details are also presented in the relevant chapters. A more detailed description of archaeological excavations and various site locations can be found in the following publications: Clark (1949, 1950, 1954, 1972); Moore (1950, 1954); Schadla-Hall (1987a, 1987b, 1988, 1989, 1990); Schadla-Hall and Cloutman (1985); Lane (1998); Lane and Schadla-Hall (submitted).

1.10 Previous Palaeoecological Studies

Over the last 50 years there has been a dense concentration of palaeoenvironmental work within the Vale of Pickering (Figure 1.7). The main discoveries from this large body of work are summarised below and within Table 1.3. However, it serves to illustrate that most of this work has been concentrated along the west and north-western margins of the former lake, leaving the southern and eastern areas relatively unresearched.

1.10.1 1940s and 1950s

The very first investigations into the geology and past environments of the eastern Vale of Pickering were undertaken by Moore (1950). He concluded that the sediments were a result of sedimentation within a glacial lake and had been interrupted by a period of intense cold. Following Moore's initial investigations, Walker and Godwin (1954) undertook a series of detailed palaeoecological analyses as part of the unique programme of wetland archaeological analysis at Star Carr (In: Clark 1954).

A general description of the deposits in the Vale was made possible by a sequence of stratigraphic transects across various parts of the basin. This identified a Late-glacial solifluction layer that decreases in thickness towards the centre of the lake, and bisects the deposition of marls. This was followed by the analysis of several pollen profiles from various locations in the area (see Figure 1.7). These preliminary pollen diagrams, sampled at fairly wide intervals, allowed no more than a broad environmental reconstruction and established a rough chronology for the occupation. With the exception of a single profile from Killerby Carr, all analyses were restricted to the western end of former Lake Flixton. No human related disturbance episodes were discovered despite analysis of profiles that spanned the occupation layers at Star Carr and Flixton Site 1. The early people were assumed to be *'taking advantage of the rich fauna of the forests whilst still leaving the forest virtually untouched'* (Walker and Godwin 1954:67).

1.10.2 1980 to 1988

It was not until the 1980s that a detailed sub-surface contour and palaeo-environmental survey of the north western and western part of the basin was undertaken by Ed Cloutman and Frank Chambers under the direction of Prof. Alan G Smith. This 'in the field' stratigraphy work of Cloutman (1988a) is very useful in setting out with precision, certain lake and vegetational boundaries at different times in the Holocene. The sediment distributions and levels of the stratigraphic units are very variable, which Cloutman (1988a:6) attributes to 'local depositional factors'. Consequently there was considerable variation in the vegetation of the lake margins during the early Mesolithic period (Cloutman 1988a, 1988b; Cloutman and Smith 1988; Innes 1994). The combination of contour and stratigraphic sections also proved of critical importance for developing the archaeological investigations and formed the basis for the subsequent palaeo-environmental work.

Following the results from these stratigraphic transects (Cloutman 1988a), the set of ecosystems present in the basins and the resulting deposits can be broadly summarised as:

1. open water   calcareous mud

2. marginal open water   fine detritus mud

3. reed swamp   reed peat

4. fen carr   woody coarse detritus

5. dry land   inorganic hillwash/? humic deposits
(taken from Simmons *et al* submitted)

By dating various organic samples from selected contour levels at eight sites around the old lake edge (Cloutman 1988a), it was also possible to estimate a broad timescale for the different climatic zones of the Windermere Interglacial, Late-glacial and Holocene. Those dates are as follows:

Climatic Zone	Start of Zone (^{14}C yr BP)	End of Zone (^{14}C yr BP)
Windermere Interglacial	>12,010±130 (CAR-842)	c. 11,000±110 (CAR-880) to c. 10,960±110 (CAR-841)
Late Glacial Stadial	c. 11,000±110 (CAR -880) to c. 10,960±110 (CAR-841)	c. 9930±90 (CAR-883)
Holocene	c. 9930±90 (CAR-883)	

Cloutman (1988b) and Cloutman and Smith (1988) also made a 3-Dimensional study of the palaeoenvironments at the sites of Star Carr and Seamer Carr (Table 1.3). Such studies have provided the detailed environmental context for those sites described in the previous section (Section 1.9). This detailed work provides an important insight into the complexity of the environment and the vegetation changes across a series of islands within the lake, all of which were at different stages of in-filling and lake succession during the early Mesolithic.

Despite reconstructing the vegetation in great detail across much of the north-western side of the lake, these analyses were not able to demonstrate any appreciable modification of the environment by the early Mesolithic hunter-gatherers, a feature in common with the work by Walker and Godwin (1954). This is despite taking a pollen profile from the archaeological trench VP85A at Star Carr, adjacent to the wooden platform which lay directly above a discrete charcoal horizon.

Further research along the western edge of the lake was undertaken by Innes in the late 1980s (Figure 1.7 and Table 1.3; Innes 1994; Simmons *et al* submitted). He re-analysed the sites of Flixton 1 and Flixton 2, which were originally investigated by Walker and Godwin (1954), in order to assess the effects of peat dehydration on the preservation of the organic micro-fossils. Innes concluded that preservation levels within the peats had deteriorated over the last 30 years but that the peat had become

compacted rather than truncated. His research also included the analysis of two newly excavated sites VPD and VPCG along the western edge of the lake.

At this last site, VPCG, the pollen diagram traversed a stratigraphic horizon that included Mesolithic flints located directly below a thick charcoal layer. Pollen analysis provided information which suggested a link between the rise of hazel and human activity within the Vale, as well as providing possible indications of vegetational response to human occupation. Although this work was undertaken before the research by Petra Day (Day 1993, Section 1.10.3) the results were not published until later.

Innes' final piece of work used a series of pollen monoliths that were taken from what appears to have been a very significant and important site within the Vale, VP88D (see Section 1.8, earlier). Regrettably preservation at the site was so poor that pollen levels were uncountable and no environmental evidence could be determined. In fact, *'The lack of countable pollen in the important site of VP88D is typical of the loss of information being suffered at the moment'* (Innes 1994:4). The absence of palaeoeconomic information about a potentially important site like this is very worrying, as VP88D may be a vital piece of the overall jigsaw puzzle that represents the early Mesolithic occupation of the Vale.

In summary, up until the late 80s there was no definitive palaeoecological evidence for early Mesolithic human modification of the environment at Star Carr or any of the sites nearby, despite the results of research into the Mesolithic elsewhere by other authors, e.g. Smith (1970), Edwards (1989), Behre (1986). However, more recent work has been able to make use of advances in palaeoecological techniques e.g. fine resolution sampling and microscopic charcoal analyses, and as a result increased detail and precision is now possible.

1.10.3 1989 -2000

In 1989 excavations under the supervision of Prof. Paul Mellars reopened Trench A (VP85A) of Schadla-Hall (1988), in order to recover new samples for palaeoenvironmental work. Using combined pollen, charcoal, macrofossil and

sedimentological analyses Petra Day, now Petra Dark, working for the McDonald Institute for Archaeological Research at Cambridge, investigated the effects of human activity during the occupation layer at Star Carr. By using pollen samples estimated to represent 2-4 years in depth, Day was able to investigate vegetation change in much more detail than achieved during any previous studies (Day 1993).

Day's preliminary results from Star Carr (Day 1993), revealed small time scale fluctuations in the woodland and lake edge vegetation which were associated with periods of archaeological activity. Peaks in macro and microscopic charcoal roughly correlated with dips in the frequency of male fern (*Dryopteris filix-mas*) and increases in birch (*Betula*) and grasses (Poaceae) (Table 1.3). This was provisionally interpreted as human impact at the time of the timber platform (9640±70 ^{14}C yr BP, OxA-3349). This was followed slightly later by an episode of mineral inputs into the lake, suggesting that at some point disturbance was significant enough to have caused soil destabilisation. Human activity is postulated to have disturbed stands of male fern and created areas of bare soil. This provided the opportunity for grasses and birch seedlings to colonise the newly created areas.

The occurrence of a radiocarbon plateau at c. 9600 ^{14}C yr BP and c. 10,000 ^{14}C yr BP (Becker and Kromer 1986, 1991; Becker *et al* 1991; Kromer and Becker 1993; Mellars 1990), caused problems for the chronological placement of the early Mesolithic archaeology and palaeoecology. Events separated by up to c. 400 calendar years were indistinguishable by radiocarbon dating. In order to avoid this problem (Day and Mellars 1994) tried to 'wiggle match' several closely spaced, carefully selected radiocarbon accelerator dates from the occupation at Star Carr. The successful result of the wiggle matching enabled periods of early Mesolithic occupation to be 'absolutely dated' for the first time.

In various publications (Day 1993; Day and Mellars 1994; Mellars and Dark 1998; Dark 2000), Dark has since demonstrated that there were at least three phases of occupation near the location of trench A at Star Carr. The first started at c. 9650 ^{14}C yr BP (c. 10,920 cal BP) lasting for c. 80 calendar years whilst the second started at c. 9400 ^{14}C yr BP (c. 10,740 cal BP) lasting for c. 130 calendar years. Both phases of

settlement resulted in the disturbance of birch, aspen and fern communities and coincided with peaks in charcoal deposition. The third phase of occupation occurred at Clark's original site, with most of the occupation dating to c. 9400-9100 ^{14}C yr BP. The actual nature of the vegetation disturbance during this phase is unclear.

Further analysis of the macro charcoal from Trench A by Jon Hathers from University College London, indicated burning of reeds (*Phragmites*), willow (*Salix*) and aspen (*Populus*) populations at the lake edge, potentially during the late spring to early summer (Hathers 1998 in Mellars and Dark 1998). Day (1993; Dark 1998) suggested that this was either caused by accidental spread of fire from hearths or due to deliberate management of the reed beds at the lake edge. The occupation phases indicated by the charcoal curves varied in intensity throughout the phases of occupation resulting in multi-peaked charcoal deposition, probably also a result of variations in the spatial location of activity.

Finally Day (1996a) published a long palaeoecological profile from the western end of the lake basin c. 500 m to the east of Star Carr (see Figure 1.7). Using combined pollen, charcoal and sedimentological analyses Day reconstructed the former vegetation and fire history from the Windermere Interstadial c. 13,000 ^{14}C yr BP until c. 6515±85 ^{14}C yr BP. In addition to providing a broad regional and chronological context for the early Mesolithic human activity within the western end of the lake, Day was able to demonstrate a short-lived climatic deterioration during the Windermere Interstadial but prior to the Loch Lomond Stadial. Furthermore, Day also demonstrated the problems of dating within calcareous lakes, the potential presence of *Alnus* during the late-glacial and the occurrence of pre-Holocene fire events. Day proposed that charcoal peaks that occur at c. 12,000 ^{14}C yr BP were due to human activities, as there is evidence for archaeological activity within the Windermere Interglacial (see Moore 1954; Schadla-Hall 1987a). *'It is possible that some areas of open woodland and scrub were burned'* (Day 1996a:19), either accidentally or to attract game.

It seems probable that prior to 1993, the lack of evidence for early Mesolithic vegetation disturbance was solely due to the lack of microscopic charcoal studies

and the wide sampling intervals of the pollen diagrams. It is therefore highly possible that human groups also modified the vegetation and environments around other sites within the Vale e.g. the sites at Seamer Carr and the PhD sites presented here. Unfortunately, due to the location of the waste disposal site which now lies on top of Seamer Carr, we may never find out the nature of the vegetation disturbance around those sites. This means that any information obtained from the rest of the lake will be of even greater significance.

The ground breaking work by Day (1993, 1996a); Day and Mellars (1994); Mellars and Dark (1998) and Dark (2000), although of undeniable importance, has once again concentrated primarily on Star Carr and its immediate surroundings. Thus prior to this present study almost all palaeoenvironmental research within the Vale has been concentrated along the north-western/western side of former Lake Flixton leaving the majority of the former lake edge unresearched (Figure 1.7).

1.10.4 2000 – Present

The only work to have actually concentrated on the very eastern and south-eastern deposits of the Vale, were two pieces of work funded by the Vale of Pickering Research Trust (Cummins 2000b, 2001). Both profiles, PCC and QAA, were taken from the southern edge of the lake (Figure 1.7 and Table 1.3) and were analysed after most of the fieldwork for this PhD had been completed.

PCC, located on the southern lake edge, contained the partial skeleton of an early post-glacial *Bos primigenius* which died within a swamp environment, whilst QAA was unassociated with any archaeological artefacts. Both pieces of work reconstructed the lake-edge vegetation and fire history from c. 13,000 to c. 9000 ^{14}C yr BP and provide the longest Upper Palaeolithic pollen sequences to have been retrieved from the shallow lake-edge peats. They demonstrate that there were at least 3 short-lived declines in birch prior to the late-glacial which may correspond to possible short-lived temperature declines identified from other palaeoenvironmental data in North-west Europe and Greenland e.g. Björck *et al* (1998). The two profiles also demonstrate that pre Holocene fires were fairly frequent around the southern edge of the lake. Some of these fire events were apparently quite large and show up

at several locations, whilst others were apparently fairly localised. Unfortunately neither profile contained any associated archaeology that could be related to these Upper Palaeolithic fire events.

Then, shortly after the start of the late-glacial there was a significant rise in water level/or a significant increase in rainfall at both locations causing *Sphagnum* peat to be overlain by organic muds or marls. Finally during the early post-glacial c. 9000 ^{14}C yr BP there is charcoal evidence to support a period of early Mesolithic human activity close to QAA. Conversely, at PCC there is no evidence for any fire activity or human modification of the vegetation, although the pollen sample resolution is probably insufficient for studies of this kind.

1.10.5 Archaeological and Palaeoecological studies from the wider region

There are several regions outside of the Vale which could have been exploited on a seasonal basis by the Vale of Pickering inhabitants or may have been included within their social network or seasonal resource area e.g. the Wolds, Holderness and North York Moors. Figure 1.8 illustrates the density and locations of early Mesolithic archaeological sites in northern England, as well as other sites mentioned within the text. These areas are important for our understanding of the potential seasonal resource base and social networks of these early hunter-gatherers and the environments that they exploited. For example there is prolific evidence from the nearby North York Moors for vegetation disturbance attributed to human activity, particularly during the later Mesolithic (e.g. Simmons 1969, 1996; Simmons *et al* 1982, 1985; Simmons and Innes 1996a,b,c; Jones 1976a,b; Spratt and Simmons 1976). It was these discoveries that led Clark (1972) to hypothesise that the occupants of Star Carr were seasonally linked with the sites on the North York Moors.

1.10.6 Summary of main points arising from previous palaeoecological studies

- The sediments were deposited in a pro-glacial at the end of the last glaciation and sedimentation continued through to the mid Holocene.
- The lake micro-topography was very variable and produced a mosaic of vegetation communities and successions.

- There has been a dense concentration of palaeoecological work along the west and north-western edges of the former lake. Prior to 1993, no palaeoecological studies had detected any human impacts on the vegetation.

- Using fine resolution pollen and charcoal analyses, Day (1993, Table 1.3), showed that early Mesolithic human activity at Star Carr probably disturbed stands of male fern and created bare areas of soil. This provided opportunities for grass and birch seedlings to colonise these newly created areas.

- It seems probable that prior to 1993, the lack of evidence for early Mesolithic vegetation disturbance was solely due to the lack of microscopic charcoal studies and the wide sampling intervals of the pollen diagrams.

- Day and Mellars (1994) realised that a radiocarbon plateau at c. 9600 ^{14}C yr BP meant that events at Star Carr that are separated by up to 400 calendar years, are virtually indistinguishable using conventional radiocarbon dating.

- Day and Mellars (1994) used careful, closely spaced dating of macrofossils to 'wiggle match' dates across the radiocarbon plateau and provide absolute dates for the occupation at Star Carr.

- There were at least three phases of human occupation at Trench A at Star Carr between c. 9650 and 9100 ^{14}C yr BP (c. 10,920 to 10,150 cal yr BP).

- Each occupation lasted for a considerable time varying from c. 80 to 130 calendar years in total (if intermittent) duration.

- Analysis of macroscopic charcoal remains using electron microscopy revealed that reeds, willow and poplar were burnt at the lake edges in late spring to early summer (Hathers 1998).

- A regional pollen diagram from the western side of the lake (Day 1996a) revealed the presence of pre-Holocene fires and the possibility that *Alnus* was present during the Late-glacial.

- Most palaeoecological research has been concentrated around the western and north-western edges of the lake, leaving the majority of the lake unresearched.

- The two palaeoecological profiles that have been analysed from the southern lake-edge (Cummins 2000b, 2001), span the Windermere Interglacial and

late-glacial. They show that pre-Holocene fires were frequent but varied in extent, that water levels fluctuated in the late-glacial and that there may have been at least three pre-late-glacial climatic deteriorations.

1.11 Sites Investigated in this study

Following the results of Day (1993, 1996a), Day and Mellars (1994) and Mellars and Dark (1998), it is possible that the vegetation of the lakes and their margins, as well as the dry land, was manipulated by human communities from very early prehistoric times.

This present study provides an opportunity to increase our understanding of these early Mesolithic exploitation and resource procurement strategies, through detailed and spatially fine-scale studies of the environment around three previously un-researched sites. As the important sites around Seamer Carr, can no longer be investigated in terms of small-scale vegetation changes, this means that any information obtained from the rest of the lake will be of even greater significance.

This present section introduces each of the three new sites; Flixton School Field, No Name Hill and Barry's Island (Figure 1.9), and explains why they were chosen. All three sites have been located (or re-discovered) and partly excavated by the VPRT. A fourth area (the Regional Profile) located in the centre of the Vale, was also investigated and acts as a 'control site'.

Information regarding the on site locations and on site archaeology are provided in each of the relevant chapters (Chapters Three to Nine), so that the nature of any vegetation change or environmental impact can be interpreted in association with the available archaeological data. Likewise, any differences or similarities between the sites can then also be compared and contrasted (in Chapter Ten). Such analyses will allow the present study sites to be considered within their local and regional contexts and will also enable the Vale to be considered as a whole settlement unit instead of merely individual sites. Ultimately it may be possible to develop models of land use and seasonal movement within the landscape. Comprehensive descriptions of the

archaeological excavations and various site locations can be found in Lane (1998) and (Lane and Schadla-Hall submitted).

1.11.1 The Regional Profile (Chapter Three)

The Regional Profile (D3) is a 6.7 m core taken from the very centre of the Vale, as far away from any archaeological sites as possible (Figure 1.9). The pollen from this core should represent the regional 'natural' vegetation and will act as a 'control site' for comparison with the other archaeological profiles.

1.11.2 No Name Hill (Chapters Four- Seven)

No Name Hill or Moore's Site 3 (TA 0400 8140), is located approximately 1200 m to the north east of Star Carr and just 800 m to the south-east of Seamer Carr (see Figure 1.9). The site was chosen as it potentially represented an island settlement surrounded by deep, wet, peat which was 'guaranteed' to contain well preserved pollen (re: deteriorating peat preservation). The site was also chosen to lie at the northern end of a north-west/ south-east vegetation transect across the Vale, with the regional profile acting as the mid point. In addition, as No Name Hill is very near to a number of other early Mesolithic sites e.g. Star Carr, Seamer Carr and Flixton Island, it provided an ideal opportunity to investigate the spatial patterns of charcoal deposition. If charcoal deposition was very localised, then charcoal from nearby occupations e.g. Flixton Island, would not show up on the No Name Hill profiles and vice versa. Flixton Island is only 250 m away.

A total of three pollen diagrams were analysed from the island. Two were from the north side of the island (NAQ, NAZ), including one which was directly associated with occupational debris (NAZ), and a third profile was taken from the south side (NM).

1.11.3 Flixton School Field (Chapter Eight)

The early Mesolithic site at Flixton School Field (TA 0485 8013) is located on the southern edge of the Vale, approximately 1.9 km to the south east of Star Carr, on what would have been the southern lake edge of Palaeo-Lake Flixton (Figure 1.9). The site was chosen as it represents a lake shoreline settlement, situated on a

promontory which jutted out into the lake, similar to Star Carr. At the start of the study Flixton School Field had also produced an extremely wide scatter of flints, indicating that it was potentially a large and significant settlement. Perhaps similar to VP88D, but this time relatively well preserved. As the full extent of the site had not yet been defined, the excavations were to continue alongside the palaeo-environmental analyses. Finally, the location of the site would allow it to form a rough, south/north vegetation transect with No Name Hill.

Only one profile (FS) was analysed from this site.

1.11.4 Barry's Island (Chapter Nine)

The site called Barry's Island (TA 0613 8042) was formerly a large island located at the south-eastern end of Lake Flixton (Figure 1.9) The site was chosen as it potentially represented another large (and very complex) island settlement. The bone assemblage from the island was also the largest that had been excavated in recent years. In fact, it was large enough to allow the implementation of statistical analysis and palaeoeconomic interpretations of the site function. In addition, the lithic assemblage looked as if it were derived from a number of settlements of varying ages and it was hoped that palaeoenvironmental analyses might be able to distinguish between these different phases of occupation. Finally, Barry's Island was at the southern end of the north-west/south-east vegetation transect across the Vale.

Two profiles were analysed from this site; LAP from the northern island edge and LAL from the western shore of the island.

Chapter Two - Methodology

2.0 Methods

This chapter outlines the methods used during the present study. The study formed part of a programme of environmental archaeological research, which ran parallel to the archaeological excavations. It was carried out in order to help inform and direct the archaeological excavations and increase our understanding of the economic strategy of the hunter-gatherers and their impact on the local environment.

2.1 Field Sampling Methods

2.1.1 Subsurface Contouring and Site Identification.

Since the re-commencement of archaeological excavations in the Vale in the mid 1970's, a systematic sampling strategy has been implemented along the edges of the former lake. The eventual aim was to test-pit the edge of the entire lake at c. 20m intervals to define the location of, and excavate, as many early Mesolithic sites as possible, before peat oxidation and desiccation destroyed the organic record entirely. The initial location of these test pits was determined by the basal topography of the former lake shoreline, as past experience had shown that early Mesolithic finds were concentrated at approximately c. 24.5 m OD (Schadla-Hall 1987a, 1987b; Schadla-Hall and Cloutman 1985).

In order to locate the 24.5 m OD contour, it was necessary to construct a subsurface contour map of the lake using subsurface and surface levels taken systematically at regular (10-25 m) intervals across a grid. The stratigraphic data were obtained by the Vale of Pickering Research Trust volunteers over a period of approximately 25 years of fieldwork, using surveying equipment and a Hiller borer (Lane 1998). To date the western, north-western, southern and south-eastern parts of the lake Flixton basin have been mapped. This data were digitised by Barry Taylor (formerly of the University of Durham, Department of Archaeology), to produce a pictorial representation of the microtopography of the area similar to Figure 2.1.

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In addition to identifying the best areas in which to position test-pits, the map provides a picture of the topological environment upon which areas of dry land, fen, open water and vegetation can be superimposed for various time-periods in the Holocene, as described in Chapter One (see also Cloutman 1988a, 1988b; Cloutman and Smith 1988). This topographic information will be extensively utilised in the present study.

Once flint or bone finds had been discovered, further trenches were opened up and excavated, to try to delimit the extent of the archaeological activity. New archaeological 'sites' are identified or defined by the density of their flint and bone scatters in the initial test pits and subsequent excavation trenches. Just prior to the commencement of this study and during subsequent field seasons, two new sites were discovered (Barry's Island and Flixton School Field), and the approximate location of another of Moore's sites (Site 3-No Name Hill; Moore 1950) was relocated. These three sites form the basis of this present study (Figure 2.2).

2.1.2 Sampling at the Archaeological Sites

Palaeoecological sequences were retrieved from as close to all three sites as possible, with the aim to investigate potential human disturbance of the vegetation. However, the exact location of the profiles was often also influenced by the pollen preservation within the deposits, although whenever possible samples were taken directly from the archaeological trenches.

Over the last 40+ years the level of organic preservation in the Vale has deteriorated significantly due to repeated and intensified drainage as described in Chapter One. Previous palaeoecological studies (Innes 1994; Day 1993) had revealed that the preservation of pollen at the lake edge was not always guaranteed. Quite often only the very basal sediments had sufficient preservation to enable pollen analyses to be carried out, with analysis of the archaeologically significant shallow peats becoming increasingly laborious or impossible. The patchiness of the preservation is however complex. In order to ensure that all profiles collected for this study had reasonable levels of preservation, systematic preservation tests were carried out prior to sampling, using a temporary 'field laboratory' (Faegri and Iversen 1975).

The majority of samples were retrieved from 2 x 2 m trenches of varying depths. The sediment face of the trench was first levelled up and then scraped clean to remove any *ex situ* deposits. Retrieval of sediments was undertaken using a sequence of 10 x 10 x 50 cm monolith tins, placed stratigraphically beneath one another so that an overlap of c. 5 cm occurred at the top and bottom of each tin, except in trench NAZ where only one tin was removed. The exact section of the trench that was sampled e.g. the north or south facing side of the trench, varied depending on the deposits and archaeological finds. Upon retrieval, the monoliths were wrapped in polythene to prevent contamination and refrigerated at temperatures below 4°C until required.

2.1.3 Additional Palaeoecological Sampling

In order to obtain a record of the natural, unaltered vegetation it was necessary to take a core from the deepest part of the ancient lake as far away from the archaeological deposits as possible. This long profile, acts as a regional 'anchor' and control site for the whole study. Previous work by the Vale of Pickering Research Trust volunteers suggested that the best location was mid way between Barry's Island and No Name Hill at location D3 (Figure 2.2, TA 049 809). The sediments were retrieved using a Russian Corer in 0.5 m segments with 5 cm overlap at each end. Each 0.5 m section of sediment was transferred from the corer to semi-circular plastic tubing before being encased in polythene and stored in a refrigerator at temperatures below 4°C until required.

2.2 Analytical Methods

The monoliths and cores were analysed using the principal methods of stratigraphic, pollen and charcoal analysis. Additional supplementary analyses were carried out whenever appropriate e.g., molluscan assemblages, microscopic fungi and particle size.

2.2.1 Stratigraphic Descriptions

The seven profiles utilised in this study, were described in the laboratory using the stratigraphic methods of Troels-Smith (1955). Each profile is presented as a

lithological diagram in the relevant data chapter, accompanied by a full sediment description to provide additional detail. The stratigraphic descriptions of the pollen profiles can then be used to build up a picture of the sediment deposition and progression of the lake hydrosere at those specific sampling points.

2.2.2 Pollen Analysis

2.2.2.1 Pollen Sampling, Identification and Presentation

Samples of 0.2-0.5 cm^3 at intervals of 0.1-4 cm for the Flandrian and 4-8 cm for the Devensian Late-glacial were prepared for pollen analysis following standard procedures (detailed in Appendix 1). The exact sampling interval depended on the profile in question, the archaeological period, and the preliminary results obtained. A known concentration of *Lycopodium* spores were added and the sample was suspended in silicon oil (Berglund and Ralska-Jasiewiczowa 1986) to allow the calculation of pollen concentrations and charcoal area concentrations.

Pollen was counted on a Nikon microscope at x400 magnification using x600 or x1000 for detailed identifications. Pollen and spore types follow Moore *et al* (1991) while vascular plant nomenclature follows Stace (1991). A minimum of 500 identifiable fossil land pollen (including Cyperaceae) were counted except during very low concentration periods e.g. 'stadial' phases of the Late-glacial, where a minimum of 300 grains were counted due to time constraints. For the purposes of pollen diagram interpretation, *Corylus avellana* type is considered to be composed entirely of *Corylus* because the ecological environment was too calcareous to support large amounts of *Myrica gale*. Certain species of fungal spores can also provide important ecological information (van Geel 1986). Therefore, during pollen counting the slide was also scanned for fungal spores and a tally of the numbers of particular spores was also kept e.g. *Neurospora* and *Geoglossum* ssp.

Unidentifiable palynomorphs were counted and classed according to Cushing's (1967) categories, with the exception that degraded and corroded palynomorphs were classed as one type and with the addition of an extra category for 'concealed grains' following Birks (1970). The recording of these indeterminable grains was undertaken in order to identify any distortions in the pollen data caused by

differential preservation and depositional factors, such as oxidation, corrosion and compaction (Sangster and Dale 1961, 1964; Faegri and Iversen 1964; Havinga 1964; Delcourt and Delcourt 1980). However, the interpretation of degraded grains is more problematic (Cushing 1964, 1967; Birks 1970). As yet the causes of pollen deterioration are not well understood and are compounded by the fact that some grains are more susceptible to deterioration than others (Faegri and Iversen 1964). Recording the percentage of poorly preserved grains within the sediment might reveal the extent of differential pollen preservation within the sediment (Day 1990). To some extent the totals in some of the unidentifiable categories may also reflect the preparation methods used rather than the sediment history (Day 1990; Hall 1981).

Percentage calculations are based on a sum of total land pollen plus spores (TLP&S). Percentages for aquatics are expressed as a percentage of TLP&S. The datasets were zoned and diagrams produced using *TILIA* and *TILIA Graph* (Grimm 1991). Local pollen assemblage zones were determined from the results of constrained incremental sum-of-squares cluster analysis (CONISS; Grimm 1986), using a square root transformation and chord distance dissimilarity measure for all the pollen and spores taxa. To avoid the difficulties which may arise from percentage calculations alone (Moore *et al* 1991), pollen concentration diagrams were also calculated, which reflect absolute changes in the abundance of each taxon. Pollen concentrations may also increase with decreased accumulation rate and so total pollen concentration diagrams can serve as a useful indication of sediment accumulation rates through time.

The pollen and sedimentological data are described together within the framework of their local assemblage zones (LAPZ) in the relevant chapters. However, the numbering of each of the zones has been adjusted to coincide wherever possible with the regional vegetation zones of D3 (Chapter Three). This enables easy correlation between the profiles for future discussion (Chapters Seven and Ten).

2.2.2.2 Pollen: Interpretation and Taphonomy

There are many problems associated with the interpretation of pollen diagrams (see Moore *et al* 1991) and in order to interpret the pollen record a number of taphonomic factors need to be considered and understood. Taphonomy encompasses the processes affecting a material from the moment of its production to the point at which it is sampled (Webb and McAndrews 1976; Patterson *et al* 1987).

Differential pollen production was taken into account during interpretation of the diagrams using the adjustment factors compiled by Faegri and Iversen (1975) and Andersen (1970). The potential contribution of pollen from streams, e.g. the Wolds, Sweetbeck and Derwent was also considered, especially during interpretation of the low arboreal vegetation phases of the late-glacial (see Peck 1973; Bonny 1976; Pennington 1979; Moore 1979b).

A wide range of other taphonomic factors have also been considered at various points during the course of the study e.g. differential preservation and the spatial problem of defining the nature, magnitude and duration of impact in pollen profiles (Edwards 1979; Faegri *et al* 1989; Moore *et al* 1991). These issues have all been discussed extensively within the academic literature and so they are only referred to here, in the appropriate chapters, as and when required. Taphonomic considerations relating to the study design are discussed in Section 2.3.

2.2.3 Charcoal Analysis

2.2.3.1 Charcoal Analysis: Sampling, Identification and Presentation

For the purposes of this study charcoal is defined as 'jet black, opaque, angular particles' that are also lustrous and irregular (Patterson *et al* 1987:9). It differs substantially from the relatively recent depositions of 'spherical carbonaceous particles' (SCP) which are derived from the burning of coal or oil, and which are not relevant to this study (Griffin and Goldberg 1981; Renberg and Wik 1985).

The amount of microscopic charcoal contained within the samples was estimated using size class particle analyses during routine pollen counting. Estimates of charcoal area per slide were calculated using a standardised eye piece graticule with grid squares.

Charcoal areas were recorded using factors and multiples of the grid squares (after Waddington 1969; Swain 1973, 1978; Cwynar 1978). The results were grouped into four size classes: < 410 μm^2, $>410<1750$ μm^2, $>1750<8800$ μm^2 and >8800 μm^2 (following Clark *et al* 1989). Pollen slide charcoal >8800 μm^2 in size is hereafter referred to as 'macro charcoal particles' as some structural definition is often possible under light microscopy. No analyses of pollen sieve residues were undertaken due to time limitations.

An absolute minimum of 100 *Lycopodium* or 100% of the total *Lycopodium* count (whichever was the smallest), was used to determine the sample area. The charcoal area could then be expressed as a percentage of the Total Land Pollen or as a concentration. Both pollen and charcoal concentrations relate to volume of sediment.

Charcoal:pollen ratios (Swain 1980) were also calculated in order to provide an extremely useful index for tracing 'true' fires. Charcoal:pollen ratios relate the abundance of charcoal to the abundance of pollen, and serve as a check on whether the charcoal abundance is changing as a consequence of sedimentary changes affecting all sedimentary particles. Maxima in the ratio may also occur when post-fire pollen production is decreased as a result of vegetation burning (Tolonen 1986).

2.2.3.2 Charcoal: Methodological Issues

Microscopic size class area counts were the preferred methodology for this study as they are useful for recording low concentrations of charcoal (Patterson *et al* 1987). The distribution of size classes may also be an important factor in the interpretation of charcoal curves. Research by Pitkänen *et al* (1999) has shown that an increase in the proportion of largest charcoal particles and a decrease in particles c. <10 μm in diameter (100 μm^2) within a pollen slide, can suggest the occurrence of low intensity local fires. Rhodes (1996) was also able to distinguish *in situ* fires from *ex situ* fires by correlating between 6 geometric charcoal size classes. However Rhodes's (1996) data was obtained from specific moorland soil profiles and the application of the technique to other soil types has not yet been tested. Unfortunately, the same research has also shown that the treatment of pollen samples with Hydroflouric Acid (HF) alters the size class distributions of the particles, causing the larger particles to

be broken down (Rhodes 1996). However, the total area of particles per sample should remain unchanged, and as not all samples were subjected to HF it may still be possible to obtain important additional information from some of the charcoal size class data as shown in Pitkänen *et al* (1999).

In her studies at Star Carr, Day (1993, 1996a) and Dark (1998) used Clark's (1982) point count method for estimating the area of charcoal per dry weight of sediment. However, in order to compare the results between the two studies both methods need to be comparable. According to Moore (1999) results obtained from point count versus size class analysis are broadly similar in distribution but with peaks at different levels, enabling the general trends to still be identified. Patterson *et al* (1987) also compare results between the two methods and find them to be broadly comparable (see Table 2.1 and Figure 2.3). Thus, despite the different methodologies, it should still be possible to identify any unifying trends between the two sets of data which will allow the data from this present study to be correlated with Day's work in later chapters.

By measuring charcoal at the various different study sites it should at least be possible to build a broad spatial picture of fire in the landscape as "*...charcoal from small fires will be deposited locally, and give erratic records from site to site, depending on occupation frequency and intensity. Charcoal from large fires will be widespread, giving smooth records that are similar from site to site*" (Bennett *et al* 1990b:640). The degree of synchronicity of the fire episodes across a large enough region will also help to elucidate the human or climatic origin of the fire when it is in doubt, as a regionally synchronous event in the early Holocene is unlikely to be human in origin.

2.2.3.3 Charcoal: Interpretation and Taphonomy
'The almost ubiquitous presence of charcoal associated with the palynological evidence underlies the use of fire' (Jacobi *et al* 1976). The question is for what? This remains a major obstacle to the interpretation of charcoal data.

Origins of the microscopic charcoal

Charcoal is an impure form of carbon produced from the incomplete combustion of biomass. The present study assumes that charcoal is derived purely from the burning of vegetative material in some form, with minimal contributions from other processes (see Head 1983). It also assumes that depletion of charcoal from mechanical breakdown or oxidation is minimal (Seiler and Crutzen 1980; Schneour 1966).

In pre-industrial sedimentary sequences, charcoal peaks are assumed to reflect either; natural fires, domestic use of wood or human induced burning of the vegetation. There are no causal implications in the charcoal record and the distinction between 'natural' and 'anthropogenic' fire ecology must be inferred from the data alone. However, the scarcity of fires in European temperate woodland means that some distinction can be made (Rackham 1980, 1988; Chandler *et al* 1983; Peterken 1996). Consequently, the value of charcoal in determining the role of human interference in the structure and composition of woodlands has been highlighted by many authors (e.g. Iversen 1941; Tolonen 1978; Simmons and Innes 1981, 1987; Edwards 1988, 1989; Clark JS *et al* 1989; Bennett *et al* 1990b; Caseldine and Hatton 1993; Morrison 1994).

For the purposes of this study, fire formation can occur in three different environments; woodland, grassland and heathland. The specifics of each of these types of fire are discussed in (Moore 1999 and Rhodes 1996). However the basic requirements of fire formation remain the same:
- accumulation of dry material
- a dry enough climate
- correct atmospheric composition
- some mechanism of combustion

(after Cope and Challoner 1985).

Methodological Problems

A number of serious methodological and interpretative errors still exist within microscopic charcoal analysis. These range from differences in obtaining data, to

visual estimation and results from different techniques that are not comparable (see Section 2.2.3.2 above; Waddington 1969; Mehringer *et al* 1977; Clark RL 1982; Clark JS 1988b; Patterson *et al* 1987; Horn *et al* 1992). There are still even uncertainties in the correct identification of charcoal (Patterson *et al* 1987; Renberg and Wik 1985; Wiltshire *et al* 1994).

Taphonomic Processes

The taphonomic processes affecting microscopic charcoal are also very poorly understood. Taphonomic studies have been approached through studies of pollen taphonomy, which has resulted in an over simplification of what is essentially a very variable and complex process.

Charcoal differs from pollen in a number of ways as it is dispersed from an irregular and poorly defined source, and whereas pollen is generally spherical, robust and between 20-40 μm, charcoal can be irregular, variable in size and density and is inherently fragile. Although, like pollen, charcoal is transported by wind and water, its formation is dependant on a number of complex variables. The stage, temperature, type and duration of a fire all affect its charcoal emission rates and formation. At present there is a distinct lack of knowledge concerning the complexity of the whole process, the dynamic properties involved and the vast variety of fuel and environmental characteristics (Lobert and Warnatz 1993:16), especially the differences between charcoal production in different plant communities (e.g. Umbanhowar and McGrath 1998 and Scott *et al* 2000). Even once the particles have been generated, the mechanisms of dispersal are still poorly understood, dependant on the conditions at the time and the depositional environment, all of which are unique to each sample site. In addition, several post depositional factors need to be considered e.g. re-deposition, focusing, compaction, time lag and recruitment area of the charcoal.

Our current state of knowledge of the mechanisms of charcoal dispersal and deposition in air and water, and post-depositional factors are summarised in Moore (1999) and Tables 2.2 - 2.4. The hypotheses are often conflicting due to lack of definitive research studies.

Despite these problems, it is clear that it is possible to reconstruct fire histories from microscopic lake charcoal (e.g. Swain 1973; Bradbury 1996; Pitkänen *et al* 1999), although interpretation of the data is not straightforward. Many researchers have experienced significant problems (e.g. Battson and Cawker 1983; Swain 1973, 1978, 1980; Patterson 1978; Bradbury 1986) and it is clear that a greater understanding of the taphonomic processes is critical to the interpretation of microscopic charcoal in the palaeoecological record. Without such knowledge our unambiguous and comprehensive interpretation of the charcoal record is limited (Battson and Cawker 1983; Clark R L 1983; Anderson *et al* 1986).

Within this study charcoal concentrations and macro particles >8800 μm^2 are used to define periods of human fire activity within the local landscape. The background level of charcoal concentration is defined using data taken from the regional profile (Chapter Three). Charcoal:pollen ratios are then used to identify 'true' peaks rather than peaks caused by differences in sediment accumulation.

2.2.4. Molluscan Analysis
2.2.4.1 Mollusca: Sampling, Identification and Presentation
The Molluscan population of a sample can reflect the water depth, clarity, degree of aquatic vegetation and in some cases prevailing climate of the surrounding environment at the time of burial.

Mollusca were extracted from the marls of profile NM (only) by slicing it into 1cm units and washing these through sieves to 500 μm aperture, as recommended by Sparks (1961). The residues were oven dried at 40°C and sorted under a x10-60 magnification light binocular microscope. Mollusca were determined to species (except *Pisidium* ssp.) using the identification guides of Macan (1977) and Kerney (1976). *Pisidium* species were not determined to species as they are more difficult than gastropods to identify, as many of these species are morphologically similar (Giles 1992). The results are presented in Chapter Four as a diagram of absolute abundance per unit volume of sediment, plotted against sediment depth.

2.2.5. *Particle Size Analysis*

2.2.5.1 Particle Size: Sampling, Measurement and Presentation

Analysis of the particle size distribution of an inorganic layer can help to elucidate the origins of transport of the material, the contemporaneity and conditions of deposition.

Samples of approximately 1 cm^3 from selected horizons within the minerogenic deposits of LAP (only), were analysed for their particle size distributions. A known dry weight of sample was sieved through a 2 mm mesh and the dry weights of the >2 mm and < 2 mm components were measured again. The <2 mm component was made up to a known volume using distilled water and analysed using a Coulter Counter Machine (McCave and Jarvis 1973). The results are displayed in Chapter Nine as curves showing the percentage composition of different sediment sizes at different depths throughout the inorganic deposit.

2.3 Study Design and Justification

In this study the catchment characteristics and morphometry have been predetermined by the location of the archaeological sites, and thus cannot be optimised to produce the best results. The sampling strategy will instead have to be modified to minimised the potential problems and biases of the data and take into account any taphonomic and depositional limitations.

2.3.1 Lake size and Pollen source area

A sedimentary pollen assemblage consists of pollen derived from a variety of sources ranging from within a few meters to hundreds of kilometres away from the sedimentary basin. The transportation of the pollen rain relates to the sample area, as shown in Figure 2.4, with the pollen rain composed of the following groups:

Pollen Rain Classification	Source of Pollen
Local	Within 20 m of the site
Extra-local	20 m to several 100 m
Regional	Greater distances
Extra regional	Very great distances

(after Tauber 1965, 1977; Janssen 1966; Jacobson and Bradshaw 1981; Prentice 1985).

Only basins with a total surface area of <1ha are likely to have a pollen record composed predominantly from the local vegetation (Jacobson and Bradshaw 1981; Bradshaw and Webb 1985; Jackson 1990). Pollen from a very large lake such as Lake Flixton which had an estimated surface area in the region of 375 ha, therefore had a predicted pollen source area of c.75 000 km^2. The pollen rain from such a lake would have had a ratio composition of 1:7:2 (trunk, canopy, general rainout -Tauber 1965, 1967) and would be essentially regional in composition.

2.3.2 The Regional Profile (D3)

The regional pollen must be known in a detailed way before the local presence of plant taxa at other sites can be proven. As discussed above, a pollen profile from the centre of the lake (profile D3), should illustrate the regional pollen rain and therefore reflect the natural vegetation.

Several researchers have demonstrated that one profile from a lake or mire *'is adequately reliable'* (Edwards 1983:601) to produce a reliable vegetation history of the surrounding area, (e.g. Turner 1965, 1975; Edwards 1983; Simmons and Innes 1988; Turner *et al* 1989, 1993; Beaudoin and Raesoner 1992). Therefore D3, from the centre of palaeo-Lake Flixton, should provide a reliable picture of the natural vegetation, against which to compare the other profiles.

2.3.3 Multiple Profile Strategy

On the other hand, there can be considerable intra-site pollen variability over distances of 1 to several 100 meters (e.g. Turner 1975; Walker and Lowe 1977; Turner and Hodgson 1979; Barber and Twigger 1987; Cloutman and Smith 1988; Whittington *et al* 1991). This intra-site variability is particularly important in the

elucidation of more localised spatial variation in human impact on the vegetation. It is the degree or significance of the differences that are then interesting. Thus if we are to detect variations in forest composition or spatial differences we will need a number of cores from different areas. The density of palaeoecological sites within the Vale and the additional information from the present study site, should be sufficient to allow the detection of some of these spatial differences.

2.3.4 Sampling at the lake edges

Sønstegaard and Mangarud (1977) examined the lateral variation in pollen content from a transect 550 m in length. The herb pollen (NAP) values were generally lower in the centre of the lake than at the edge. According to Jacobson and Bradshaw (1981) this is because closed forest pollen does not travel >20-30 m from its source with the representation of local pollen decreasing within 30 m of the forest edge (Caseldine 1981; Tinsley and Smith 1974; Edwards 1982). Therefore, in order for this study to consider the composition and potential human impact on the terrestrial vegetation the samples must come from within 20-30 m of the forested environment and we are required to sample at the lake edges e.g. the archaeological trenches.

The high influx of pollen from nearby vegetation is assumed to swamp pollen brought in from above the canopy from more distant sources therefore enabling the reconstruction of the local rather than the regional vegetation (Tauber 1965, 1967; Jackson and Dunwiddie 1992; Davis *et al* 1971). Disturbance at the forest edges may be especially detectable because removal of trees or disturbance of vegetation creates steep microclimate gradients and increases diversity (Matlack 1994). In the case of Flixton School Field, the local topography of the area, a sheltered basin between land promontories, should provide a sheltered site and enable more local representation of the taxa in the deposits.

2.3.5 Pollen Re-deposition and Mixing

Once pollen has reached the lake, one of the main factors affecting pollen accumulation is lake morphometry (Davis RB 1967; Waddington 1969; Swain 1973; Davis M B *et al* 1984; Lehman 1975, Larsen and MacDonald 1993). Other factors include; geology, soils, vegetation, hydrology and climatic influences. Davis MB

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(1968) showed that pollen is often re-suspended and re-deposited when it reaches the lake environment, this particularly occurs in shallow water where it is then re-transported to the lake centre (Edwards and Whittington 2000). This causes the pollen signal in the lake centre to be effectively averaged. Wind induced currents are the main factors causing sediment mixing (Davis MB 1968; Davis and Brubaker 1973; Davis *et al* 1984; Lehman 1975) although animal burrowing is another factor. In fact according to Larsen and MacDonald (1993), in shallow lakes such as Lake Flixton, sediment mixing occurs principally due to frequent currents and bioturbation. This re-deposition and mixing will be a considerable factor in the uniformity and consistency of pollen counts from the lake centre, creating an average of several years deposition. Pollen counts from profile D3 should be therefore appear to be smoothed accordingly.

2.3.6 Fine Resolution Sampling

In palaeolimnological studies the dynamic nature of the lake sediments (especially perhaps at the lake edge) causes problems, and the adoption of fine resolution pollen analysis in parts of this study requires us to question the validity of these methods. Although fine resolution sampling is essentially the same as conventional pollen analysis *"the fineness of the temporal scale does call into question some of the basic assumptions of the technique"* (Simmons *et al* 1989:209).

Tippett (1964) demonstrated the reasonable assumption that pollen is deposited within the same year of production, so when taking a sample of 0.1 cm one should be dealing with a sample of just a few consecutive years in duration. However, that would only be true if the lake sediment has chronological integrity across its entire diameter. This is not always assured when using lake sediments and it may mean that pollen from one year also occurs in the next sample. In truth, little is actually known about pollen deposition at the lake edges. It is assumed in this study, that the band of lake edge vegetation around much of Lake Flixton during the early and later Mesolithic (Cloutman 1988a, 1988b; Cloutman and Smith 1988; Day 1993; Edwards and Whittington 2000) acted as a sediment trap and minimised any reworking or slumping of the deposits, with deposits remaining *in situ* once deposited. Mellars and Dark have also demonstrated little reworking of the charcoal found at Star Carr.

Unstratified (unlaminated) lacustrine sediments, can be closely sampled but there is no way of knowing the exact length of the time represented by each sample (Davis R B 1967; Green 1983). If there was any post deposition mixing or bioturbation this would set a limit to the resolution that can be achieved, i.e. the deposits become averaged. The internal resolution of a sample at the scale of the sample thickness, is assured when the pollen diagram shows evidence of both gradual and abrupt changes in pollen frequency, in a sediment that has accumulated continuously. Breaks in the accumulation are the only other factor which could have given rise to abrupt changes. If post-deposition mixing had occurred the pollen signal will have been essentially smoothed. Thus fine resolution diagrams will need to exhibit the following characteristics before their internal resolution can be accepted:

i.   isolated high or low frequencies which reflect unusual events such as bad flowering seasons and sudden disturbances e.g. wind-throw or fire.

ii. gradual pollen changes indicative of longer term vegetation changes, which also ensures against sediment hiatuses.

If post-deposition mixing occurs in any of the study samples it can be identified by the nature of the pollen diagram and interpretations limited accordingly (Green 1983; Turner and Peglar 1988). It is hoped that fine resolution pollen analysis will yield far more detail regarding prehistoric vegetation change in the early Mesolithic than the conventional method of pollen analysis which produces a compound assemblage over many years (e.g. see Simmons *et al* 1989).

2.3.7 Taphonomic issues affecting the Charcoal Study design

From Table 2.3 and 2.4 one could assume that the ideal sampling situation for charcoal would be within a closed catchment with "...*close-interval [contiguous] sampling where sediment mixing [and redeposition] is minimal, the entire lake catchment burns at once, fire frequency is low for each portion of the landscape, and charcoal delivery from the local fire is high*" (Clark 1988a:74-5). It is clear that not all these criteria can be satisfied (or even identified) during this study, but the sampling strategy undertaken here can at least try to maximise the results.

2.3.7.1 Charcoal deposition at the lake edge

The local fire regime in (a particular part) of Lake Flixton, may best be reflected at the lake edges where the slope of the lake bottom is gentle, the local topography provides a sheltered location with (hopefully) significant local pollen and charcoal input. Reedswamp and lake edge vegetation was well established very early on in the post-glacial history of the lake (see Cloutman 1988a, 1988b; Cloutman and Smith 1988; Day 1993, 1996a; Mellars and Dark 1998). Such vegetation bands are assumed to have provided a stabilising sedimentary environment for charcoal and pollen deposition, and thus provide an *in situ* record of vegetation and fire history without undue secondary deposition. The integrity of the data can be attested to by the analysis of the fine resolution pollen curves which should indicate that minimal post deposition mixing occurred. The sediment core from Flixton School Field (at this stage) appears to fit this scenario reasonably well, although the profiles from No Name Hill and Barry's Island appear slightly less suitable due to less shelter and steeper depositional environments. The suitability of these cores may not become fully apparent until fine resolution pollen diagrams spanning a particular charcoal peak have been constructed.

2.3.7.2 Fine Resolution sampling of charcoal

During such analyses the minimum sampling width for charcoal counts (as opposed to pollen) need be no less than 5 years (c. 0.5 cm depending on accumulation rates) with the final fire resolution dependant on the fire frequency (Clark 1988a). When sampling occurs at less than 0.5 cm intervals because of pollen analysis, the charcoal counts can be amalgamated and the median value calculated. Clark (1988a:67) states

that *"In the absence of sediment mixing the pollen-slide method should consistently resolve individual fires that occur with an expectation of >30-50 years"*. Therefore, once a period of fire activity has been identified, it is unlikely that this study will be able to detect anything other than broad periods when fire was or was not used, as may be the case with permanent domestic fires or the regular use of land fires. Perhaps it will not even be possible to determine the duration of human activity (see Day and Mellars 1994), as due to taphonomic factors, transient fire use or occupation may still appear to occur over long periods. As Millspaugh and Whitlock (1995:14) so aptly state, *"..the shape of a charcoal peak reveals more about the taphonomic history of charcoal within the lake and watershed following a fire than about the amount of biomass that was burned"*.

2.3.7.3 Charcoal contained within Peat

Finally, not all the sediments analysed in this study are derived from lake deposits. The progression of the lake hydrosere was spatially and temporally very variable, and many deposits are composed of peat. Charcoal horizons in such deposits should be interpreted with caution due to the fact that peat can burn potentially removing some of the environmental record, and sub surface burning can also occur at depths of some meters, including the horizontal spread of fire (Moore 1982; Christjakov *et al* 1983).

2.4 Dating

Radiocarbon dating of archaeological artefacts and critical sediment horizons was undertaken in order to establish a chronology of events and produce an independant dating framework.

2.4.1 Dating methods

For a detailed description of the scientific methods behind radiometric dating procedures, calibration of dates, contamination and pre-treatment of samples, readers are referred to Olsson (1986) or Pilcher (1991), although specific problems relating to this study are discussed below.

Radiocarbon dating of the sediments was problematic due to the calcareous nature of much of the sediments and their distance from dry land (see hard water error, Section 2.4.2.1 below). Sample selection was therefore based on the presence of terrestrial macrofossils or key palaeoecological/archaeological horizons. Whenever possible, macrofossils were identified to species prior to radiocarbon dating. Due to the limited number of suitable macrofossils in most of the sediment profiles it was often necessary to date other deposits, preferably peats. Peats were predominantly comprised of reeds and sedges, although some other non-terrestrial plants may have formed a small component of the sample as it was not feasible to identify the entire sample to species. If lake detritus was used for dating, this was because there was no other suitable material available and the sediment was being used to date a critical horizon, on the assumption that wrong dates were still better than no dates. Sampling of organic detritus had (in most cases) apparently provided representative dates at Star Carr (Cloutman 1988a; Cloutman 1988b; Cloutman and Smith 1988). One bone sample from Flixton School Field and one bone sample from No Name Hill (NAZ) were also submitted for radiocarbon dating to try to establish a link between the palaeoecological evidence and the archaeology.

Samples were submitted to Beta Analytic Radiocarbon Dating Laboratory for AMS or Radiometric dating. The AMS method of dating was used for the majority of the sediments as it requires a smaller sample size, and can be used when there is very little available carbon, or where fine resolution and thus high precision dates are required. Even when a particular sample material is prolific and contains a high amount of carbon (e.g. peat), AMS dating allows a reduction in the stratigraphic width of sample, permitting a decrease in the standard error of the dates. Dating results are reported separately within each data chapter where they are interpolated to provide age-depth curves and rates of accumulation. Dates are reported using ±2σ or 95% probability.

Due to financial constraints only a limited number of samples could be dated during this research programme. As a result many of the relative dating and chronological comparisons, are based on dates obtained from other palaeoecological studies from the area, with taxa from the regional profile used as chronological comparisons e.g.

Innes (1994) and Simmons *et al* (submitted), but particularly those obtained by Day (1993, 1996a); Day and Mellars (1994); and Mellars and Dark (1998).

In the absence of an independent and 'absolute' dating framework for the study sites, an alternative, relative, dating framework is also proposed in Chapter Ten. This uses 'apparent' regional fluctuations in the male fern (*Dryopteris filix-mas*) curve, to compare the timing of the different occupation phases.

2.4.2. Radiocarbon Dating: Methodological problems

2.4.2.1 Hard water error

The fact that the Vale of Pickering is a limestone catchment and that Lake Flixton would have been a hard water lake, posed considerable limitations on the dating of the deposits. In these circumstances, unless purely terrestrial material is submitted for dating a 'hard water effect' may occur. The hard water error occurs when a plant takes its carbon almost entirely from the carbonate rich water of the lake instead of from the atmosphere (e.g. Shotton 1972; Deevey *et al* 1954). Reservoir effects (e.g. Olsson 1972) can also bias the result of a radiocarbon date. They occur when the dated material has used a $^{14}C/^{12}C$ source that is lower than that of the atmosphere. For example, when old carbon has been incorporated into the dated material during inwashing. Both effects result in an artificially 'old' date for the material. As a result the date cannot be used as a reliable chronological marker.

Peat deposits, on the other hand, are unlikely to contain a hard water error if they are deposited at the edge of the lake. This is because even if a plant has its roots in the water, providing most of the plant is above water level, the plant usually takes its ^{14}C from the atmosphere. Thus peat composed of reeds, rushes and sedges will not generally display a hard water effect when dated (Housley 1998). However, peat deposits from hard water lakes which combine remains of both aquatic and atmospheric plants will contain a dating bias. It is therefore possible that some of the peat samples dated in this study may be subject to a small hard water error due to the mixed nature of the sample. The reliability of each dated sample has been assessed by Housley (1998), and is discussed in the appropriate chapter.

2.4.2.2 Radiocarbon Plateaux

A link between the dendrochronologically dated master oak sequence and the 'floating' early post-glacial pine sequence has enabled the extension of the ^{14}C calibration curve back to 10,000 ^{14}C yr BP (Becker *et al* 1991; Kromer and Becker 1993; Becker 1993). This means that any radiocarbon date from the present back to 10,000 ^{14}C yr BP can be converted to calendar years BP (cal BP). Calibration beyond the limits of the calibration curve is not yet possible, but one might expect vast variations and fluctuations caused by rapid climate changes (see Pilcher 1991:Figure 3).

However, research over the last fifteen years has also revealed major irregularities in the radiocarbon time-scale curve which covers the late-glacial and early post-glacial deposits. Radiocarbon plateaux have been identified at 10,000 ^{14}C yr BP and 9650 ^{14}C yr BP (Becker and Kromer 1986, 1991; Becker *et al* 1991; Kromer and Becker 1993). Results from Swiss lake sediments also suggest a further plateau at 12,700 ^{14}C yr BP (Amman and Lotter 1989; Zbinden *et al* 1989). Within each of these plateaux the ^{14}C ages remain effectively unchanged over a period of centuries and so rates of change and the length of particular episodes are normally impossible to determine (see Radiocarbon Plateau at 9600 ^{14}C yr BP from Star Carr, shown in Figure 2.5). The ^{14}C plateaux are caused by fluctuations in the concentration of atmospheric ^{14}C, which in turn are probably attributable to variations in solar activity, ocean circulation changes and the release of isotopically 'old' carbon during periods of rapid climate and environmental change (Struiver and Braziunas 1993; Shackleton *et al* 1988).

The occurrence of these plateaux has serious implications for the dating of palaeoecological and archaeological episodes within the present study, as a single radiocarbon determination cannot provide a close date for a particular site or event within the range of the plateau. The radiocarbon plateau between 9650-9550 ^{14}C yr BP occurs at a critical period in the early Mesolithic and corresponds to 350 solar years (Becker and Kromer 1986:962). As a direct result the 'early Mesolithic' lasts for over 1400 calibrated years (Mellars 1990), with the dating of episodes of human occupation sometimes appearing synchronous. The only way round this problem is

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to use 'wiggle matching' (see Day and Mellars 1994), to provide absolute calendar dates (see Figure 2.5). Such 'absolute dating' methods have an accuracy comparable with dendrochronology (Pilcher 1991) but require a detailed sequence of short-lived and high precision dates over a short stratigraphic sequence of deposits.

Due to financial constraints only a limited number of samples could be dated during this research programme. As a result the interpretation of the data is heavily reliant on the 'wiggle matched' dates obtained by Day and Mellars (1994; also Mellars and Dark 1998). These dates are: *"...in a sense the bedrock which underpin much of the chronology of the Holocene within the early Mesolithic period for the Vale of Pickering..."* (Housley 1998:35). He has already established that the dates provide valid age estimates because *"... if there were any significant problems with these measurements the calibration curve would not have been reproduced.."* (see Figure 2.5).

Future palaeoecological dating analyses from the Vale of Pickering should consider using AMS pollen dating (e.g. Brown *et al* 1989; Eriksson *et al* 1996; Richardson and Hall 1994; Regnell 1992), to increase dating precision, eliminate reservoir dating errors and enable 'wiggle matching' of dates.

2.4.3. Radiocarbon Dating: Presentation of Results

2.4.3.1 ^{14}C yr BP vs. cal BP

All dates quoted in this study are uncalibrated and presented as ^{14}C yr BP, unless stated otherwise. This is due to the radiocarbon plateaux in the late-glacial and early post-glacial (see above), which means that several calendar dates will have the same ^{14}C. However, during inter-site comparisons and correlations, both ^{14}C and cal BP dates are presented e.g. in Chapter Ten. When cal BP dates are used, the date represents the mid-point of the calibrated age range at the 2σ confidence level.

2.4.4 Interpretation of Radiocarbon Dates

When interpreting the results of radiocarbon dating, several considerations need to be taken into account. These are:

i.   Does the date accurately portray the actual age of the sediments or the horizon that is being dated?

ii.   Is the date a correct age measurement?

iii.   How precise is this measurement?

iv.   Is it comparable to other dates?

These questions and how they relate to this study have been discussed at length in Housley (1998), but are also outlined in Table 2.5. The reliability of each of the study samples has been assessed by Housley (1998), and is discussed in the appropriate chapters.

2.5 Analytical Methods/ Statistical testing

This study has taken a multiple core approach and as a result an important aspect of the study is the comparison and correlation of pollen and charcoal diagrams at various spatial scales.

Comparison of pollen diagrams by eye can be incredibly difficult, especially when it is not clear which part of one sequence resembles that of another. Consequently, *"..caution must be exercised in attempts to correlate these sequences on the basis of changes within the pollen curves alone, as sequences at varying distances from the lake-edge would have undergone different stages in succession at different times."* (Dark 1998:148). All the pollen diagrams in the present study are first zoned within the appropriate chapter, using a statistical program (CONISS, Grimm 1986) before comparison to the regional profile. This then provides an objective zonation of the diagram at each sampling location. The profiles are then compared to the regional profile in order to establish a chronology of vegetation change and human occupation within the Vale, and to highlight any hiati. Careful correlation between profiles is then attempted in Chapters Seven and Ten.

Differences in pollen source areas between all the profiles, demonstrable by the percentage differences between the birch and male fern curves at the different localities, serves to invalidate the use of conventional statistical tests to compare the pollen profiles (see above and Chapter Seven). Thus, although apparently inadequate, visual correlation and comparison between profiles is the still the most useful analytical tool.

2.5.1 Analysis of Human Impact

The Early Mesolithic is in many ways the focus of this thesis but just because there is prolific evidence for human settlement of the lake area at this time does not mean that every vegetation fluctuation must be attributed to a human agency. Palynologists have often "*siezed upon the existence of prehistoric communities to help explain the changing palaeofloras*" (Edwards 1982:5). Climate is still likely to have been an important factor influencing the vegetation.

In order to detect human impact on the vegetation in the early Mesolithic, it is necessary to use an independent marker such as charcoal, because the vegetation was changing so rapidly. Due to the lack of natural fires in the temperate woodlands of England during the early Mesolithic (Rackham 1980, Moore 1996, Tipping 1996), periods of persistent charcoal input are attributed to the activities of humans, at least from the start of the Holocene onwards. Charcoal analysis is crucial in order to detect human induced changes to the vegetation. Prior to 1990, the apparent lack of palaeoecological evidence to support early Holocene human impact in the Vale, was probably a direct result of the lack of charcoal studies

Even though the presence of charcoal indicates that human activity may have occurred, it is impossible to establish the scale or degree of this impact, in an environment where the vegetation is constantly fluctuating. Climatically controlled-regional and/or local changes to the pollen output of the vegetation will also occur concurrently, as climate is likely to be as important to the vegetation, as the activities of humans, the status of the soils and the amount of competition. Any human impact on the vegetation will then be superimposed upon these natural background fluctuations and the human induced changes will not necessarily be discernible by themselves. (These background

variations will subsequently be referred to as BV). Therefore, before one can make any comments about the effects of early humans on the vegetation of the Vale, it is necessary to establish the degree of any natural changes that are taking place (BV). As both human induced changes and natural changes may be occurring concurrently.

Analysis of human impact in each profile is therefore undertaken using a three-stage model. The first part of the model is subjective (Human Impact Test-1), and uses visual analysis of the pollen and charcoal data using conventional analyses of human impact (e.g. Faegri and Iversen 1989; Moore *et al* 1991). The second and third tests use objective, statistical tests to see if there is significant disturbance of the vegetation at the archaeological site compared to the regional and natural vegetation. First of all the confidence limits of the data are considered (Human Impact Test-2) i.e. is the variability in the pollen data 'real' or an artefact of the methodology or inherent variability in the data (IV)? (Is the disturbance of the archaeological vegetation greater than that would be expected due to variations in the calculation of the pollen percentage data?) This is done using a pollen program called PSIMPOLL (Bennett 1992, 1994, 2002), which calculates the 95% confidence levels of the data (Mossiman 1965; Faegri *et al* 1989). Any pollen changes that do not exceed the 95% confidence limits cannot be confidently attributed to human impact.

The third stage of the Model (Human Impact Test-3) assesses whether the pollen variations in the archaeologically-linked profiles, also exceed the natural, background variations in pollen output (BV). This is undertaken using fine resolution analyses of the lake centre sediments to establish the degree of pollen variability in the absence of human impacts. This part of the model is only applicable to the early Mesolithic before the establishment of *Corylus*, when human impacts on the environment e.g. by fire, are considered to be non-regional in scale (see Tipping 1996). The lack of competition and stress between pioneer plant species also means that soil and climate will be the overriding factors affecting the pollen sum. These background variations from the regional profile are then scaled and applied to the lake edges. The exact methodology is described in Chapter Three, following the analyses of Background Variations (BV) in the regional profile.

2.5.2 Inter and Intra-site comparisons

When it comes to *between site comparisons*, rather than relying solely on subjective comparisons, it would be preferable to have an unbiased, repeatable and absolute measure of dissimilarity, to determine the extent to which the profiles differ. However, the author proposes that it would be unwise to undertake *extensive* statistical comparisons *between* the lake edge profiles from the same or different archaeological sites, due to their differing depositional environments. Each pollen diagram will be unique due to its relative position at the lake edge and affected by different taphonomic factors e.g. different pollen source areas and preservation status. The use of SLOTDEEP or similar computer packages were considered but the software was unavailable to the author at the time of analysis of the data.

2.5.3 Summary of Statistical Analyses

In summary the following analytical methods will be used:

2.5.3.1 Subjective visual tests of the data:

   i.   Visual comparison with the regional profile e.g. each site chapter.

   ii.   Carefully considered visual comparison with the other pollen and charcoal profiles e.g. Chapters Seven and Ten

   iii.   Identification of broad similarities between the *Betula* and *Dryopteris filix-mas* curves at different sites.

2.5.3.2 Semi-objective tests of the data:

   iv.   Constrained cluster analyses to identify similarities between the local assemblage zones.

2.5.3.3 Objective tests of the data:

Despite the inability of statistical programs to aid in the correlation and comparison between the different profiles, statistical analyses are still useful to compare certain parts of the data set.

The following statistical programs or methods will be used:-

v.   Identification of the range of expected 'natural' variations in the fine resolution pollen data from profile D. Considering the amplitude of these 'natural' variations (BV + IV), can we say anything about human impact (HI)?

vi.   Production of a threshold level for disturbance indicators. i.e. To be significant the lake-edge pollen values must be greater than the 'natural' values at D3.

vii.   PSIMPOLL (Bennett 1992, 1994)- To compare archaeological profiles with the natural vegetation. PSIMPOLL is used to identify the 95% confidence limits for a pollen count. PSIMPOLL is particularly useful as it can *"elucidate the uncertainty and true variation associated with the pollen percentages and, therefore, help assess and explain differences within and between pollen diagrams."* (Dumayne-Peaty and Barber 1998:159).

In addition, the following packages will also be used selectively as an additional aid to the actual interpretation of the data:

CALIB 4.3 - used to convert uncalibrated radiocarbon BP dates into calibrated calendar years BP/BC.

Not all techniques described above will be applied to every core. CALIB will aid in the establishment of a relative chronology of human impact whilst subjective, semi-objective, and statistical analyses may help to elucidate any patterns and associations in the vegetation changes caused by human actions. In all cases it must be borne in mind that with the use of lacustrine sediments, there is always the possibility that post-depositional processes may be responsible for the differences between the pollen profiles (e.g. Whittington *et al* 1991).

2.5.3.4 Statistical Omissions

The data would have lent itself to a number of other statistical tests such as: multivariate statistics i.e. TWINSPAN or simple correlations between species and charcoal values, to establish the type of vegetation being affected (if any). Although

these options would have been potentially valuable tools when attempting to unravel the complexities of the data, they were omitted from this study because:

- There are lots of limitations in the application of statistical analyses to palaeoecological data, mainly due the proliferation of 'unknowns' in the data.

- Changes in the pollen of 'indicator species' (illustrating potential human disturbance) are very small and thus cannot truly be considered to be statistically significant.

- The assignment of statistical thresholds and indicator groups to the pollen data for use in TWINSPAN would itself introduce an element of subjectivity into the analyses.

- The changes in the data may be entirely composite and thus it would be impossible to establish a causal link.

- Preliminary assessment of the data suggested that an in-depth analysis of the data at this stage would perhaps be fruitless. It is afterall entirely possible to read too much into the data and to chase a solution when in fact a solution is unlikely to be found.

Lack of time and easy access to the available software also influenced the extent of the analyses.

2.6 Chapter Two – Summary.

The main points relating to methodology in this study are as follows:

- Sub-surface contouring of the lake basin by the Vale of Pickering Research Trust has identified the extent of palaeo-lake Flixton and the early Mesolithic lake-edges.

- Trial pitting at c. 20 m intervals along the 24.5 m O.D. contour has defined the location of as many early Mesolithic sites as possible, including the three sites investigated in this study.

- Palaeoecological profiles were taken from sediments as near to the archaeological remains as possible, depending on the preservation of the microfossils.

- No profiles were sampled more than 30 m away from defined archaeological activity, apart from the regional profile which is estimated to lie over 750 m

away from the nearest early Mesolithic archaeological debris. This methodology maximises the chances of recording local lake edge pollen and of recording vegetation disturbance caused by human activities.

- The pollen rain from a lake this size (c. 375 ha) should be essentially regional in composition (Jacobson and Bradshaw 1981). Nontheless, studies by other authors, e.g. Cloutman (1988a, 1988b); Cloutman and Smith (1988); Day (1993); Dark (1998) and Innes (1994) have demonstrated that that there is considerable intra-site variability around the edges of Lake Flixton. Sampling close to the lake-edge will therefore enable reconstruction of the local rather than regional vegetation.

- Fine resolution pollen and charcoal analysis was undertaken on selected profiles. Fine resolution sampling was justified as the profiles exhibited all the internal resolution characteristics defined by Green (1983), and Turner and Peglar (1988).

- Periods of possible human impact are detected by identifying peaks in charcoal concentrations (i.e. greater than regional background levels) and macro charcoal particles. An increase in larger charcoal particles and a decrease in numbers of smaller particles is also taken to indicate the occurrence of low intensity fires (Pitkänen *et al* 1999).

- The radiocarbon plateau at c. 9600 ^{14}C yr BP limits the accuracy of the results obtained from this study and prevents the establishment of an 'absolute chronology' of human occupation.

- Potential vegetation fluctuations at the lake edges are assessed using a three-stage test for human impact. The variations in pollen are first analysed using conventional methods. Secondly the fluctuations are compared to the 95% confidence limits of the pollen data, and thirdly the fluctuations are compared to 'natural' background variations in pollen output, obtained from the regional profile. The exact methodology is described in Chapter Three.

Chapter Three - The Regional Vegetation

3.0 Introduction

Before it is possible to look at the vegetation disturbance caused by hunter-gatherer communities, it is necessary to know what the 'natural' non-anthropogenic vegetation looked like, as any human disturbance of the vegetation would be superimposed upon this. This includes knowing the scale of any variations in the 'natural' production of pollen, e.g. climatic, seasonal and yearly variations in pollen output (BV). Unless the 'natural' unaltered vegetation is known at a certain point in time, then it is impossible to say that any changes are the result of human activity.

Furthermore, any human occupation of the lake region from the Upper Palaeolithic onwards, would have happened against a changing climatic backdrop. Rapidly changing climates would have initiated ecological change, causing rapid shifts in vegetation communities in addition to, and superimposed upon, those due to natural succession. Therefore, not only does this study attempt to detect human induced alterations to the vegetation, but it also attempts to isolate these changes from the 'natural' species variations and migrations caused by the rapidly changing climate. This is where the use of microscopic charcoal becomes an essential tool to infer the presence of human groups (discussed at length e.g. in Tipping 1996).

In order to obtain a record of this 'natural' unaltered vegetation, against which the results of various archaeological site-specific studies could be assessed, it was necessary to take a core from the deepest part of the ancient lake as far away from the archaeological deposits as possible (D3 in Figure 3.1). The long pollen profile published by Day (1996a) was not considered suitable, as her profile was taken only c. 400 m from the western edge of the lake, and may not adequately reflect the 'natural' changes occurring in the eastern end of the basin. It is proposed that the regional pollen profile described in this chapter, will act as a form of control site and will enable the new archaeological sites to be placed in their regional chronological and vegetational contexts. In addition to providing a backdrop to the human settlement of the area, the regional profile also provides a chance to compare and

contrast the vegetational variations in and around the lake with the work already published (e.g. Walker and Godwin 1954; Cloutman 1988a, 1988b; Cloutman and Smith 1988; Day 1993, 1996a; Day and Mellars 1994; Innes 1994; Mellars and Dark 1998), and shed more light on some of the issues those papers have raised (see Chapter One).

3.1 Coring

Work by several authors (Hicks 1985; Aronsson 1991; Hicks 1993) suggests that within a closed forest, anthropogenic pollen will be recorded at a maximum of 20-200 m from its source. Thus the deepest and most central deposits of the lake seemed the ideal location to provide a complete vegetation sequence of the natural environment. Previous work by the Vale of Pickering Research Trust volunteers suggested that the deepest lake deposits were located mid- way between Barry's Island and No Name Hill and approximately 7-800 m away from any recorded archaeological activity. In August 1995, a stratigraphic sequence was obtained from location D3 (Figure 3.1, Grid Ref: TA 049809), approximately c. 1.7 km to the east of the well known early Mesolithic site of Star Carr (Clark, 1954). The sediments were retrieved using a Russian Corer although the first 2 m of the sequence were unsampled as it consisted of dry oxidised peat. Depths were measured from the ground surface, which was levelled to a datum of 24.89 m OD.

3.2 Lithostratigraphy
The lithostratigraphy of the core is as follows (see Figures 3.3-3.4):

Depth (in cm)	Description
195-314	Dark brown detritus mud with abundant remains of aquatic plants, monocotyledons, seeds including *Potamogeton* and insect remains.
314-330	Light brown detritus mud/marl with vegetative remains molluscs and insect remains.
330-468	Brown/olive to dark olive marl with vegetative remains, molluscs and insect remains.

468-499	Pale olive marl with dense vegetative remains including reed/sedge fragments and insect remains.
499-516	Pale olive to olive, silt marl with some vegetative and insect remains.
516-534	Grey-olive clay marl.
534-538	Grey-olive silt and clay marl with occasional gravel.
538-545	Grey/olive silt clay with gravel.
545-548	Olive silt and clay marl with occasional gravel.
548-645	Pale olive silt marl.
645-660	Olive silt and clay marl.
660-670	Grey-olive silt clay.

3.3 Pollen Analysis

Sub-samples of c. 0.5 cm width were taken for conventional pollen analysis (see Chapter Two), at intervals of 1-4 cm in the Holocene and 4-8 cm within the Windermere Interglacial, i.e., Greenland Ice Core stages GI-1 (Greenland Interstadial) and GS-1 (Greenland Stadial) of Björck *et al* (1998). The sampling interval was dependent on pollen concentrations and periods of archaeological interest.

3.4 Radiocarbon Dating

Radiocarbon dating of the sediments was problematic due to the calcareous nature of much of the sediments and the lack of terrestrial macro-fossils throughout the entire sequence. Two samples were submitted to Beta Analytic for Accelerator Mass Spectrometry Dating (AMS), due to their small sample sizes. The results are shown in Table 3.1 and on Figures 3.2-3.4b).

Table 3.1   Radiocarbon Dates from the Regional Profile (D3)

Depth (in cm below datum)	Lab code	Radiocarbon yr BP	δC^{13} (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
202-209	Beta-104479	5740±50	-30.1	6675-6420	Dark brown detritus mud with abundant plant and insect remains.
321-330	Beta-104478	8370±60	-29.7	9465-9230	Light brown detritus mud/marl with vegetative, mollusca and insect remains.

3.5 Zoning the Pollen Diagram

The pollen diagram was zoned by using the computer program CONISS (as described in Chapter Two), and by correlation with pollen diagrams from the region and other areas of North-western Europe, e.g. Beckett (1981); Day (1996a); Walker *et al* (1993); Walker *et al* (1994) and Walker (1995). Zoning is undertaken in order to aid the description and interpretation of the diagrams. Correlation was undertaken by comparing the main changes in species between the various diagrams, for example: the rise in *Corylus* and the decline of *Betula*; the appearance of *Alnus*. Further sub-zones were also identified from the smaller detailed changes in the vegetation.

The different zones were dated using the two radiocarbon dates above (see Table 3.1), and by correlating the diagram with other palynological and palaeoclimatic research from North-west Europe, e.g. Walker (1995); Day (1996a); Björck *et al* (1998). The broad timing of major vegetation migrations have also been extensively mapped and dated by various authors e.g. Huntley and Birks (1983); Birks (1989). Figure 3.2 shows the zonation of the Regional Profile in relation to the zones of Day (1996a) and Björck *et al* (1998).

3.6 The Palaeoecological Sequence - The Regional Profile D

The percentage pollen diagrams (Figures 3.3-3.5) have been divided into nine local assemblage zones (prefixed D). These are:

Windermere Interstadial (GI-1) c. 13,000–11,000 ^{14}C yr

LPAZ D-1   660-604 cm   Poaceae-*Betula*-Cyperaceae-*Artemisia*

LPAZ D-2   604-564 cm   *Betula*-Poaceae-Cyperaceae

D-2a   604-590 cm   *Juniperus-Thalictrum* subzone

D-2b   590-564 cm   *Betula-Juniperus-Filipendula* subzone

LPAZ D-3   564-542 cm   *Betula*-Poaceae-*Filipendula*

Loch Lomond Stadial (GS-1)-Pre-Boreal c. 11,000-9700 ^{14}C yr BP

LPAZ D-4   500-542 cm   Poaceae-*Filipendula*

Early Holocene (early Mesolithic) c. 9700-9000 ^{14}C yr BP

LPAZ D-5   500-465.5 cm *Betula-Dryopteris filix-mas*

D-5a   500-494.5 cm *Betula-Poaceae-Filipendula* subzone.

D-5b   494.5-484.5 cm *Betula-Poaceae-Dryopteris filix-mas* subzone.

D-5c   484.5-472.5 cm *Betula*-Pteropsida-*Dryopteris filix-mas* subzone.

D-5d   472.5-465.5 cm *Betula- Dryopteris filix-mas-Corylus* subzone

Early Holocene (later Mesolithic) c. 9000 –5700 ^{14}C yr BP

LPAZ D-6   465.5-425 cm *Corylus-Betula-Ulmus*

LPAZ D-7   425-319 cm   *Corylus-Ulmus-Quercus*

LPAZ D-8   319-206 cm   *Corylus-Quercus-Alnus-Ulmus*

The mid Holocene (late Mesolithic/ early Neolithic?) c. <5700 ^{14}C yr BP

LPAZ D-9   206-200 cm   Cyperaceae-Poaceae-Pteropsida (monolete) undiff.

The pollen and sedimentological data are described together within the framework of their local assemblage zones (LPAZs), in Table 3.2.

3.7 Interpretation of the Radiocarbon Dates

The results of the radiocarbon dating (Table 3.1) can be compared to the results obtained by Day (1996a) and Cloutman (1988a, 1988b) and to other profiles from the surrounding region.

The first radiocarbon date obtained for this profile, 8370±60 ^{14}C yr BP (Beta-104478), occurs just before the initial alder rise. The alder rise has been dated to 7640±45 ^{14}C yr BP by Day (1996a, OxA-4042) but dating by other authors (e.g. Cloutman 1988b) suggests a variable date for the expansion of alder in the region. Considering the distance from the margins of the lake, a potential hardwater error is likely to have occurred in sample Beta-104478, as no differentiation between terrestrial and aquatic vegetative remains was made during sample selection. This was due to the lack of sediment volume available from the Russian core. Housley (1998:24) states that:

> "The presence of aquatic plants including Potamogeton (pondweed) in the samples, and the fact that thick slices of organic mud matrix were included, means that the ^{14}C-depleted Dissolved Inorganic Carbon (DIC) of the lake is very likely to have had an effect on the these samples......If a high proportion of the sample's vegetative matter took carbon from the lake when alive then an offset in the $\delta^{13}C$ values might be expected, but the reported $\delta^{13}C$ would seem to indicate this was small...... The bias to being too old is most likely due to the samples being of a mixed nature with some of the organic matter coming from sources that use atmospheric carbon whilst other organic matter has been using the DIC in the lake."

The second determination from this profile, Beta-104479, comes from the beginning of pollen zone D-9 and may document the first evidence for the elm decline from the region, but it requires further research for clarification. Due to the lack of individually identifiable terrestrial macrofossils, a bulk sediment was submitted covering 7 cm. This apparent elm decline has been dated to 5740±50 ^{14}C yr BP (Beta-104479), a date which is potentially too old as it is much earlier than other elm decline dates from the area such as, c. 4700 ^{14}C yr BP at Fen Bogs (Atherden 1976) and 5099±50

^{14}C yr BP at Gransmoor Quarry (Beckett 1975). One explanation may be that this is a pre-elm decline clearance phase (e.g. Regnéll *et al* 1995). Alternatively, the older date may be due to the mixed age of the sediments from what is rather a large stratigraphic span. If it had been possible to date a sample covering a smaller stratigraphic span, then the results may have been much younger. Lastly, the decrease in elm could also be attributable to the preferential deterioration of *Ulmus* grains (Havinga 1964).

Housley (1998:25) comments that:

> *"Given the sample sediment description a hardwater error cannot be ruled out, however combined with the other uncertainties already cited [above], the status of this measurement is best defined as inconclusive. It may be a valid age estimate but the associated environmental evidence to assess this is inconclusive".*

This date should perhaps then be treated as a maximum age for the deposits in pollen zone D-9. Future dating analyses should concentrate on the use of AMS pollen dating (e.g. Eriksson *et al* 1996) to reduce dating limitations and reservoir dating errors.

3.8 Sediment Accumulation Rates

A general estimate of the time taken for sediment accumulation can usually be can be obtained from the total pollen concentration curve (Figure 3.7). High pollen concentrations are taken to imply low accumulation rates and low pollen concentrations are taken to imply high sediment accumulation rates. However, when a sediment profile has accumulated over a very long timespan covering several major climatic periods, the pollen concentration curve can be misleading. This is due to e.g. the existence of low productivity environments prior to the Holocene or the sudden arrival or influx of high pollen producers such as *Corylus*. The pollen concentration curve should therefore only be used as an indicator of sediment accumulation from short duration profiles which accumulate under relatively constant climatic conditions.

Alternative estimates of sediment accumulation rates can be obtained by using radiocarbon values obtained from the lake-edge radiocarbon samples of Day and Mellars (1994) and Mellars and Dark (1998) and from other palaeoclimatic work from North-west Europe e.g. Beckett (1981); Day (1996a); Walker *et al* (1993); Walker *et al* (1994); Walker (1995) and Björck *et al* (1998). The following dates and depth values (Table 3.3.), have been used to calculate the rate of sediment accumulations in Profile D:

Table 3.3   The approximate age of sediments in D3 (see also Figure 3.2)

Approx. Depth in cm in D3	^{14}C yr BP age estimate	Approx. Cal yr BP	Lab Code /Source	Dated horizon
205	5740±50	6548	Beta-104479 Table 3.1	Elm decline in Profile D
325	8370±60	9347	Beta-104478 Table 3.1	*Alnus* rise in Profile D
465.5	8940±90	9970	OxA-4377 Mellars and Dark (1998)	The *Corylus* expansion at Star Carr
474	9385±115	10,230	OxA-4376 Mellars and Dark (1998)	The empirical *Corylus* rise at Star Carr
500	9500±70	10,780	OxA-3350 Mellars and Dark (1998)	The early Holocene increase in *Dryopteris filix-mas* at Star Carr
507	c.10,000	11,550	Björck *et al* (1997)	The start of the PreBoreal
520	c. 10,500		Atkinson *et al* (1987)	Middle of GS-1
542	c. 11,000	12,445	Björck *et al* (1997)	Start of GS-1
564	c. 11,300	c.13,200	Walker (1995)	Peak of open birch woodland in GI-1
590	c.11,800-12,000	c.14,000-13,750	Walker (1995); Björck *et al* (1998)	Climatic deterioration GI-1d?
604	c.12,500		Walker and Harkness (1990)	*Juniperus* peak in GI-1e
660	c.13,000	c.15,500	Walker and Harkness (1990)	Start of GI-1e

A time-depth curve for profile D is presented in Figure 3.8., using the data from Table 3.3.

During the Windermere Interglacial (GI-1a-e) the sediments accumulated at a modest rate of about 0.06 cm yr^{-1}, before slowing to a rate of 0.04 cm yr^{-1} during the Loch Lomond Stadial (GS-1). Compared to Day's (1996a) profile, which records c. 1 m of sedimentation, there was considerably less sediment (c. 35 cm) deposited at location D3 during the Loch Lomond Stadial. This latter figure suggests a relatively slow accumulation of sediments in the middle of the lake in comparison to the western side of the lake at this time (0.04 cm yr^{-1} compared to 0.1 cm yr^{-1} in Day (1996a)). This is probably a factor of the distance from the lake edge as during the Loch Lomond Stadial, most sediments were derived from hillwash and solifluction. Walker and Godwin (1954) describe the late-glacial solifluction layer as *"thinning towards the centre of the lake"*, consequently, as Day's (1996a) profile was considerably nearer the lake edge, it received a much higher sediment input. Although profile D contains less sediment, there is no reason to think that there is any hiatus in deposition. The whole of the Loch Lomond Stadial is thought to be represented within the pollen diagram, but it is concentrated in a small stratigraphic span.

In the early Mesolithic the sedimentation rate increased once more, and the early Holocene marls were deposited at a rate equivalent to c. 0.06 cm yr^{-1}. This latter figure still suggests a relatively slow accumulation of sediments in the middle of the lake in comparison to the western side of the lake at this time (0.11 cm^{-1} in Day (1996a)). This is probably still a factor of distance from the lake edge, combined with lower energy stream input. Day's (1996a) profile was considerably nearer the outflow of the Sweetbeck.

Assuming that the date of 5740 ±50 ^{14}C yr (Beta-104479) for the top of profile D is correct, then during the later Mesolithic the sedimentation rate increased to 0.08 cm yr^{-1}, presumably due to the higher vegetative productivity of the surrounding environment.

3.9 Pollen Preservation

During routine pollen counting a tally of unidentifiable pollen types was kept based on the categories of Cushing (1967), see also Chapter Two. Using this information a

pollen preservation curve was constructed for this profile (Figure 3.9). The following observations have been made:

3.9.1 Zones D1-D4

Unidentifiable pollen is mainly due to the amount of obscuring minerogenic material and metallic spherules within the samples, despite often prolonged treatment with Hydrofluoric Acid. Metallic spheriules are indicative of anaerobic conditions with minimal basal sediment mixing (Wiltshire *et al* 1994). Crumpled and corroded pollen also form a significant contribution to the sum, attesting to the erosional signal and secondary origins of much of the inwashed material, apart from during zone D-3, when soils were relatively stable.

3.9.2 Zone D5

Pollen preservation is generally excellent and any unidentifiable pollen types are predominantly caused by minerogenic, spherule or detrital obstruction.

3.9.3 Zones D6-D8

Preservation conditions remain excellent although a higher percentage of unidentifiable pollen grains are caused by concealment. Corrosion increases very slightly from c. 330 cm upwards as the sediment changes from marl to detrital mud.

3.9.4 Zone D9

Unidentifiable pollen reaches 20% TLP with almost equal contributions from concealed, corroded, crumpled and to a lesser extent, broken pollen grains. The reason for such high values is probably predominantly due to the oxidation and drying of the sediments, which permits bacterial decay of the organic matter. The concealment of pollen grains is probably due to the resistant nature of some of the detrital matter often found in lowland peats (Richardson and Hall 1994).

3.9.5 General Observations

Despite the highly calcareous nature of the marls (pH 6.0-8.0), the pollen preservation within them is generally excellent. The moisture content of the marls is relatively high and from this one could deduce that water content (and also by

inference, lack of oxygen), and not the pH, is the most important factor affecting the pollen preservation within this profile. This conclusion is supported by the work of Holloway (1989) and Vaughn *et al* (1994), both cited in Traverse (1994).

3.10 Early Mesolithic Fine Resolution Phase (Figure 3.10).

On completion of conventional pollen analyses, a small section (6 cm) of the core, was subjected to finer resolution pollen analyses. Contiguous sub-samples were taken at intervals of 0.25 cm, equivalent to about 4 years pollen deposition. These fine-resolution analyses were undertaken in order to ascertain the 'natural' (non-anthropogenic or climatic) variations in pollen production that occurred within the regional vegetation. Only when the non-anthropogenic variations in pollen output are known will it be possible to isolate any changes caused by human activity. By taking samples equivalent to approximately 4 years pollen deposition, the results should then be broadly comparable with the fine resolution samples examined from the lake margin deposits. Unfortunately, in the absence of extensive radiocarbon dating, it is impossible to ensure that all the pollen samples from the regional profile and lake edge profiles represent the same time-span. However, every effort was made to make sure that the fine resolution samples were broadly comparable, by calculating sediment accumulation rates.

The 'natural' non-anthropogenic variations in pollen can then be statistically compared to samples obtained from archaeological sections, to determine whether any human-induced changes have occurred (see Chapter Nine). Sampling at intervals of less than 0.25 cm would have been pointless due to the time-smoothing effect of pollen accumulation in the lake centre deposits. Finally, in case the magnitude of natural pollen outputs varied significantly over long temporal scales (perhaps according to the prevailing climatic regime), the chosen section of the core was estimated (visually) from the pollen diagram, to be roughly contemporary with the earliest phase of human occupation at Star Carr (Dark 1998).

3.10.1 LPAZ D-5b   486-492 cm

Over a period of c. 16 years (1 cm), fluctuations (>5% TLP) occur in some of the pollen taxa, e.g. *Betula* and *Dryopteris filix-mas*. This suggests that the climate and/or accumulation rate is dynamic and that detection of human interference with the vegetation will not be straightforward. The finer resolution samples provide enhanced information on species abundance and diversity e.g. the constant background diversity of herbs and constant *Pediastrum* levels, whereas conventional analyses revealed a more sporadic and low-level occurrence. This is likely to be a factor of the sample width (0.5 cm^3 v 0.25 cm^3) rather than due to any 'real' differences in plant occurrence or pollen output.

Finally, a prolonged and discrete peak in *Alnus* pollen occurs between 490.6-488.4 cm and is of considerable interest to the palaeoecologist. This relates to the ongoing debate about the possible link between human disturbance and the expansion of *Alnus* (after Smith 1970, 1984), as well as the presence of *Alnus* in Britain before the conventionally accepted date of its arrival at 8000 ^{14}C yr. BP (e.g. Birks 1989; Chambers and Elliot 1989). These topics are discussed in more detail in Chapter Eleven.

3.10.2 Preliminary conclusions relating to the fine resolution pollen sampling

In conclusion, the natural, climatic or non-anthropogenic variations in pollen production, are so great during the early Mesolithic that it will be difficult to determine the cause of any variations in the pollen diagrams. It may, in fact, be unrealistic to hope to detect any anthropogenic impacts on the vegetation using fine resolution pollen analyses. In order to detect any human impacts on the vegetation, the pollen changes caused by human activities will need to be greater than the natural variations in pollen production and will also need to be accompanied by peaks in microscopic charcoal. Statistical analysis will prove invaluable here, (see methodology in Chapter Two and results of statistical analyses in each chapter).

Detection of human impact on the vegetation generally relies on the discovery of inflated levels of 'disturbance' taxa. Ascertaining the regional background levels of these pollen types in profile D is problematic, as the pollen source areas of the lake

centre and the lake edge profiles will be very different. It will be hard to ascertain whether high levels of disturbance taxa at the lake edge are the result of human activities or merely the result of a different pollen source area. Thus, considerable care will need to be taken during the interpretation of the fine resolution pollen phases.

Another major factor for consideration is the time-width of the fine pollen samples. Any comparisons between cores will be dependant on the resolution of the sampling that has been undertaken. Without extensive radiocarbon dating it impossible to make sure that each sample represents the same time-span and is therefore statistically comparable. In summary, fine resolution pollen analysis may just add to our knowledge of natural variations in pollen output and it may be impossible to detect the human-induced changes.

3.11 The Charcoal Record

Recent work by Whitlock and Millspaugh (1996) indicates that there may be a lag of 5 years or more between catchment fires and charcoal deposition in the central or deeper parts of a lake. However, given the approximate 16 year sampling resolution throughout the majority of the core, charcoal peaks are taken to be approximately coeval with past fires. In the few instances where sample resolution is equivalent to 5 years or less (i.e. between 486-492 cm), the average charcoal values spanning a 1 cm stratigraphic span can be used to estimate the importance of past fires (Clark 1988a). Figure 3.5 illustrates the deposition of charcoal throughout the core, in association with a pollen diagram showing the percentage total composition of certain pollen groups. Charcoal values are shown as % TLP, as concentrations x 10^{-5} cm^2 cm^{-3} and as a ratio of Charcoal:pollen x10^{-5} cm^2 $grain^{-1}$. As explained in Chapter Two, there is very little concensus of opinion over what constitutes a charcoal peak and what charcoal levels are considered to be significant. It is very often down to each individual researcher to determine what he or she considers to be significant. In this study, the regional profile is used to determine the levels of 'background' charcoal. Charcoal levels lower than 50-75 x10^{-5} cm^2 cm^{-3} are taken to represent the background influx of small regional charcoal particles. Levels in excess of this are thought to indicate periods of human use

of fire. Larger charcoal particles are also thought to represent local fires (Clark 1988a; Clark *et al* 1998). Therefore in this study particles >8800 μm^2 are taken to represent local fires within 400m (Clark *et al* 1989; Tinner *et al* 1998).

Charcoal (all curves) is very abundant in the pre-Holocene record (zones D-1 to D-4), as the climate ameliorates following the deglaciation of the area. Charcoal concentrations are particularly high until the beginning of Zone D-2a. This is potentially equivalent to Greenland Interstadial-1c. At the top of zone D-4 (the Loch Lomond Stadial/Pre-Boreal, GS-1), charcoal levels are relatively high once more. At least some of this charcoal is local in origin as indicated by pieces of macro charcoal (>8800 μm^2).

Compared to some periods of the pre-Holocene, the charcoal record in the early Holocene is fairly subdued. Both the concentration data and the charcoal particle size data from sequence D suggest at least three periods of fire activity in the early Mesolithic c. 10,000-9000 ^{14}C yr BP (zone D-5), i.e. there are three peaks with greater than background levels. Charcoal:pollen ratios are relatively low in comparison to the preceding sections, although in contrast to the first half of the later Mesolithic period, these levels are still quite attenuated. Charcoal deposition peaks just prior to the *Corylus* rise at the end of zone D-5, a horizon correlated with Mesolithic activity or vegetation disturbance at lake edge sites within the Vale (see page 19; see also: Walker and Godwin 1954; Innes 1994).

A period of marginally increased fire activity produces peaks in the charcoal concentration and the Charcoal:pollen ratio curves between c. 430-420 cm in zones D-6/D-7. However, these events do not appear to have had any regional effect on the vegetation. Other significant peaks in the Charcoal:pollen ratio do not occur until zone D-8 in the later Mesolithic, despite continual deposition of large concentrations of charcoal throughout the entire period. The low Charcoal:pollen ratio is probably the result of the very high pollen concentrations produced by the canopy forming *Corylus* woodland. Such high pollen productivity and thus high pollen concentrations, is not necessarily indicative of slow sediment accumulation, (the accumulation rate is 12.3 yr cm^{-1}, which is relatively high compared to the rest of the profile). Thus, fire activity in

zones D-6 and D-7 is probably better reflected by the charcoal concentration curve. Therefore, during the later Mesolithic, fires were pretty frequent within the region. As with many profiles from Britain (e.g. Smith 1984; Cloutman 1988b; Day 1996a, Tipping and Milburn 2000), charcoal deposition in profile D increases significantly at the start of the alder rise. Fire occurrence is linked to a change in the relative frequencies of the taxa in the Atlantic woodlands and was quite local in source, due to the shallowing of the lake after this time as inferred from pollen taxa and stratigraphy.

High charcoal deposition (all curves) at the top of sequence (D-9) suggests fire activity during a phase of elm and alder decline. All these episodes are likely to be linked to the activities of Later Mesolithic people (Schadla-Hall 1987b). The high charcoal levels at the top of zone D-9 provide yet more evidence that the elm decline may merely be an artefact of the preservation conditions in the sediments, as charcoal levels generally fall at the elm decline in most pollen diagrams (e.g. Edwards 1990), although Tipping and Milburn (2000) and Parker *et al* (2002) have found evidence to the contrary.

3.12   Synthesis of Profile D

The vegetation history of the region is now discussed, from the start of the Windermere Interglacial (GI-1e) c. 13,000 ^{14}C yr BP until the end of the Mesolithic. The vegetation and environment facing the prehistoric settlers is addressed with particular reference to archaeologically documented periods of the early Mesolithic. The charcoal record is also assessed for indications of human or naturally induced fires throughout the whole period and their significance to the archaeology are discussed. No acceptable pre-Holocene radiocarbon dates are available from any of the sites in the Vale and so suggested dates for the Windermere Interglacial and Loch Lomond Stadial are based on comparison with dates from elsewhere in the region or country.

3.12.1 Windermere Interglacial

Predictive models of palaeobathmetry and palaeoshorelines by Lambeck (1995; and Figure 3.11), show that the ice sheet advance down the east coast of England which occurred at c. 19,000-18,000 ^{14}C yr BP, was only a short duration advance and had retreated by 16,000 ^{14}C yr BP. Despite this model, organic deposition in profile D

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does not commence until c. 13,000 ^{14}C yr as the climate started to ameliorate at the opening of the Windermere Interstadial sequence (GI-1) (Atkinson *et al* 1987; Walker and Harkness 1990). This sudden change in climate (approximately 7 °C T_{max},) took place *"in an immeasurably short period during which temperatures over much of northern Europe rose from glacial conditions to levels as warm, or even warmer than, those of the present day"* (Coope *et al* 1998:427).

In response to this warming, birch (*Betula*) scrub with scattered willow (*Salix*), started to spread very gradually over the landscape, although there were still large tracts of open and disturbed land and areas with pioneer herb vegetation. Pollen concentrations during this period are extremely low reflecting the low productivity of the climate and high erosion rates. Peaks in pre-Quaternary spores suggest that erosion or reworking of the sediments has occurred in keeping with the immature soil status. A suite of herb/ruderal species are present e.g. *Silene* type, Compositae Lig. and Tub., *Plantago maritima*, and Brassicaceae. This assemblage suggests an open and disturbed environment, suitable for pioneer species but with low vegetative productivity and extensive unvegetated areas.

The initially open steppe vegetation was probably out of phase with the climate but was soon replaced by a scrub vegetation and patches of birch woodland (Pennington 1986; Coope and Brophy 1972; Brooks *et al* 1997). The vegetation appears to be similar to the bottom half of LPAZ S-1 (Day 1996a), although there are notable higher proportions of *Rumex acetosa* rather than *R. acetosella* and higher percentages of *Plantago maritima*. The latter probably reflects the cold climatic conditions from the preceding stadial (GS-2, Björck *et al* 1998). Occurrences of *Filipendula, Helianthemum* and *Juniperus*, Ericales and *Thalictrum* suggest an unshaded yet closed grassland/scrub community in some areas, although pollen concentrations indicate that vegetative productivity was still very low.

This initial stage of the interglacial, between 13,000-12,500 ^{14}C yr BP, is called the thermal maximum when mean July temperatures were greater than 16-18°C (Walker 1995; Coope *et al* 1998). If temperature alone, had been the determining factor in vegetation growth then, then the climate would have supported thermophilious

forests. However in reality there was a vegetational lag of about 800-1000 years by comparison with the Coleopteran data, as vegetation slowly expanded from relict populations or migrated from glacial refugia on the continent (Walker *et al* 1993; Walker 1995). This was possible as between 18,000-12,000 ^{14}C yr BP, much of the North Sea was dry land (see Figure 3.11).

Gradually, though, as the climate became increasingly warm soils started to stabilise. Occurrences of *Filipendula, Helianthemum* and *Juniperus*, Ericales and *Thalictrum* suggest an unshaded yet closed grassland/scrub community in some areas, although pollen concentrations indicate that vegetative productivity was still very low. Fluctuations in the birch and herb curves suggest fluctuating birch scrub due to oscillating temperatures but the *Betula* concentration curve (Figure 3.6), although very low, suggests a relatively steady increase in birch cover. *Betula* pollen has not been assigned to species e.g. *B. nana* or *B. pubescens* due to the difficulty in determining sub-species under light microscopy (Prentice 1981). However, notably large numbers of *B. nana* pollen were not recognised at any point by using the measurements of Birks (1968).

By zone D-2, with the continuing amelioration in climate, birch scrub developed into open woodland with willow and juniper (*Juniperus*), although open land was still a prominent feature of the landscape. Birch communities probably contained a mixture of sub-species. Macrofossils of *B. nana* (dwarf birch) were found at Star Carr, along with remains of *B. pubescens* (downy birch) and tree hybrids of *B. pubescens* x *pendula* (downy x silver birch) in Windermere Interstadial deposits (Walker and Godwin 1954:63). These pollen assessments are supported by the work of Petra Dark (Mellars and Dark 1998:167) who found macro remains of *Betula* tree species in sediments of this date. Hybridisation between dwarf and tree birches is also likely to have occurred in the Vale of Pickering as hybridisation has been observed where the two occur locally (Elkington 1968 cited in Beckett 1981:192).

In zone D-2a there is a brief period when juniper scrub with grassland becomes the dominant vegetation type, a feature noted from several late-glacial sites in Britain (Walker 1995). Providing the biostratigraphic zones are synchronous, this episode

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could be dated to c. 12,500 ^{14}C yr BP (Lowe and Lowe 1989; Walker and Harkness 1990), a date which marks the end of the thermal maximum. As *Juniperus* occurs on dry soil at the treeline, peaks in *Juniperus* pollen are thought to reflect the onset of climatic deterioration or enhanced dryness. It is difficult to assess which particular species of *Thalictrum* were present in zone D-2, as percentage variations do not fluctuate with inferred climate changes. The pollen sum is envisaged to be made up of a mixture of different sub-species of *Thalictrum*, but *T. alpinum* is assumed.

After 12,500 ^{14}C yr BP there was a sudden deterioration in temperature of 3-4 °C, after which temperatures never reached T_{max} levels equivalent to the thermal maximum again (Walker 1995; Coope *et al* 1998). In profile D, juniper scrub was succeeded by a reversion to open grassland with large tracts of disturbed ground and stands of sea-buckthorn *(Hippophäe rhamnoides)*. Such a response may be attributable to a climatic deterioration with increased soil instability dated to c. 11,800-12,000 ^{14}C yr BP by Mangerud *et al (*1974) and Walker (1995) at their respective sites, but ranging from 12,200-11,800 ^{14}C yr BP elsewhere in Northwest Europe (Björck 1984; Björck and Möller 1987; van Geel *et al* 1989). Beckett (1981) suggests this is a period of reduced moisture as rock-rose *(Helianthemum)* is noted to exhibit some degree of drought and frost tolerance (Grime *et al* 1991) and this may infer a period of colder and/or dryer conditions which no longer favoured juniper establishment. On the other hand, these vegetational changes may just be a reflection of the dry micro-habitats of the species and the well-drained substrate they occupy, as *Hippophäe* and *Helianthemum* probably testify to the chalky and immature soils as much as they indicate the prevailing climatic conditions. The general consensus is that this vegetation change marks a deterioration in climate which has often (rightly or wrongly) been correlated to the Older Dryas. Recent work by researchers in Greenland (e.g. Johnsen *et al* 1992; Dansgaard *et al* 1993), demonstrates that there were several climatic oscillations throughout the Windermere Interstadial, equivalent to the Greenland Interstadials GI-1d and GI-1b of Björck *et al* (1998). The precise number, amplitude and synchronicity of these oscillations have yet to be established due to the poor dating control possible in most terrestrial sites from this period.

By the top of zone D2-b open birch woodland had become re-established as the climate and soils began to re-stabilise. No significant numbers of non-tree birch were observed during pollen analysis of profile D and macro remains of downy birch (*B. pubescens*) have been found in Day's (1996a) zone equivalent. From 12,000 ^{14}C yr BP onwards the sea level had been slowly increasing although it was still lower than at present and Britain was still attached to the continent.

Zone D-3 is assumed to be equivalent to the latter part of the Windermere Interstadial (GI-1a) with open birch woodland at its peak for this interstadial. Small amounts of *Salix* and *Juniperus* scrub also exist and an extensive ground flora of grasses and tall herbs like *Filipendula*. Species characteristic of disturbed soils e.g. *Artemisia*, *Thalictrum* and *Rumex* ssp. have declined significantly to almost negligible levels, suggesting soil stabilisation, but there is still a persistence of open grassland communities beneath the open woodland.

The sharp increase in birch and corresponding decline of herb communities in the middle of the zone is possibly the result of a slight temperature rise which occurred in some areas (e.g. Northern Germany and some parts of the British Isles), at the close of the interstadial. This episode is potentially dated to c. 11,300-11,000 ^{14}C yr BP by (Walker and Harkness 1990; Walker *et al* 1993; Walker 1995).

This is then followed by an apparent general downward trend in temperature with birch values declining rapidly and increased solifluction which generates an influx of sand and gravels into the lake. There are associated increases in *Pinus*, Poaceae and *Filipendula* on dry land. This sudden implied downturn in temperature is in contrast to the climatic reconstructions obtained from Coleopteran data (e.g. Coope *et al* 1998), which show a progressive deterioration in climate over a much longer timespan. *Pinus* increases at the zone end but values are still not reflective of local populations i.e. ≥25% TLP (Huntley and Birks 1983). According to Walker (1995), by c. 11,000 ^{14}C yr BP mean July temperatures had gradually declined to 12-13⁰C. The increase in pine (*Pinus*) at the top of zone D-3 may be due to a regional presence on the sandy esker soils at the valley edges, linked to cooling at the end of the interstadial. Alternatively

it may be due to long distance pollen transport from continental Europe where pine was known to be locally present (Bos and Janssen 1996; Walker 1995).

In conclusion, throughout the Windermere Interstadial (zones D-1 to D-3), the vegetation sequence broadly follows the established chronological, vegetational and climatic patterns of other work from Britain (e.g. Walker *et al* 1994; Walker 1995) and the region (Beckett 1981; Day 1996a). There are slight differences between the pollen profiles from within the Vale but these are minor and discussed later in Sections 3.13 and 3.14.

Despite several climatic oscillations (see above), scattered birch woodland with willow and juniper scrub and extensive tracts of grassland, would have been the landscape which any late Upper Palaeolithic hunters would have encountered if they had visited or settled in the Vale in this period. In fact, human groups would probably have responded rapidly to the sudden and intense warming at 13,000 ^{14}C yr BP, by moving into these new environments. Resettlement of Britain after the last glaciation would probably have taken place from the North Sea lowland or the English plain (Tolan-Smith 1998:23), although most occupation in Britain has so far been dated to at or after 12,500 ^{14}C yr BP. Although no securely dated artefacts have been found in the Vale of Pickering from contexts prior to 11,300 ^{14}C yr BP (Schadla-Hall 1987b), at Flixton 1, Moore (1951) excavated some worked flints and several fragments of bone thought to be contemporary with Windermere Interstadial deposits i.e. <13,000 >11,000 ^{14}C yr BP. There is also evidence for Upper Palaeolithic human occupation of other parts of Northern England during the Windermere Interstadial. A winter hunting event at High Furlong, Lancashire, has been dated to between 12,200±160 ^{14}C yr BP (St-3832) and 11,665±140 ^{14}C yr BP (St-3836) (Hallam *et al* 1973). Thus, it is highly feasible that at least transient settlement of the Vale of Pickering occurred at the same time prior to 11,300 ^{14}C yr BP, albeit at much lower concentrations than during the early Mesolithic. Moreover, the Vale would have provided an ideal hunting location, as the warm summer and winter temperatures must have provided optimal conditions for the growth of diverse grassland communities and provided ideal habitats for mammals such as the open country species of reindeer (*Rangifer tarandus*), bison (*Bison priscus*) and horse (*Equus* sp), as well as species more often associated with woodland habitats such as red

deer (*Cervus elaphus*), cattle (*Bos primigenius*) and elk (*Alces alces*) (Tolan-Smith 1998).

3.12.2 Loch Lomond Stadial/Pre-Boreal

Zone D-4 combines both the Loch Lomond Stadial (GS-1) and the Pre-Boreal. The climatic deterioration at the end of GI-1a is shown in the first sample of zone D-4. *"The late-glacial water temperatures were low, and the lake probably underwent winter freezing. Trophic status was comparatively low ....and there is little evidence for the development of extensive stands of aquatic vegetation other than algae, and probably Chara"* (Mellars and Dark 1998:178).

Birch woodland was soon succeeded by a periglacial/tundra environment of open disturbed grassland lacking in thermophilious species, which is characteristic of the late-glacial. This climatic transition took approximately 20-30 years to complete, based on changes in the accumulation rate of Greenland snow (Alley *et al* 1993; Kaspner *et al* 1995) or 50-70 years based on changes in $\delta^{18}O$ from Greenland ice cores (Dansgaard *et al* 1993). In contrast, transitions to the tundra-like vegetation were completed within 100-200 years.

The start of the Younger Dryas has been dated to 12,650 cal yr BP at Lake Gammelmose in Denmark (Andresen *et al* 2000) and 12,300-12,240 cal yr BP (Björck *et al* 1996) Within the region the climatic transition is dated to c. 11,220±220 ^{14}C yr BP (Birm-406) at Roos Bog (Beckett 1981), although dates vary from between 11,300 to 10,600 ^{14}C yr BP throughout the rest of Britain (e.g. Coope and Pennington 1977; Walker and Lowe 1982).

Sedimentation in the profile D during the Loch Lomond Stadial is relatively compacted. This is attributed to its location near the centre of the former lake, as the 'unsorted solifluction layer' identified by Walker and Godwin (1954:36), was described as thinning towards the centre of the lake. The whole of GS-1 is thought to be present in the pollen diagram but concentrated into a small stratigraphic span. If closer sampling had been undertaken then, more information would have been obtained, similar to zones S-3c and S-4 of Day (1996a). Little can be said about the

environment during the initial phase of the Late Glacial Stadial, however, a two-fold division of the Late Glacial Stadial can be identified, as has been recognised at a number of sites in Northwest Europe (Vandenberghe *et al* 1987; Böhncke *et al* 1993; Lowe *et al* 1994; Walker 1995; Hammarlund *et al* 1999) and displayed in high resolution ice cores (Johnsen *et al* 1992).

During this initial phase, the maximum mean July temperatures dropped to around <10°C in July, and to -20°C in January (Atkinson *et al* 1987) and there was a pronounced periglacial regime in north-west Europe with continuous permafrost, solifluction and mineral inwash (Walker *et al* 1994). *"The cold character of the Younger Dryas (Loch Lomond) can be attributed largely to the coldness of the winters"* (Isarin *et al* 1998:449), as although summer temperatures were about 3°C lower than at present, winters temperatures were an amazing 27°C lower. Birch pollen is assumed to be composed of *B. nana* (dwarf birch), as macrofossils of this species were still found in early Pre-Boreal deposits at Star Carr (Mellars and Dark 1998) and winter temperatures were unlikely to have permitted the existence of trees. It is proposed that this initial phase of maximum cold and humidity was succeeded by a less cold and relatively dry phase, about half way through the Stadial c. 520 cm in D3.

Coleopteran data suggest that warming began after 10,500 ^{14}C yr BP (Atkinson *et al* 1987) and it is this second phase which may be more clearly seen in zone D-4 at c. 520 cm, with a gradual transition into the Pre-Boreal. Dates for the close of the Loch Lomond Stadial (GS-1) and the beginning of the Pre-Boreal are also variable but it has been dated to approximately 11,550 cal yr BP (Björck *et al* 1997), with most dates falling into a band between 10,200-9900 ^{14}C yr BP (Walker and Harkness 1990).

The onset of the pre-Boreal is marked by a change to a more marl-based stratigraphy in the latter stages of zone D-4. At 10,000 ^{14}C yr BP climatic amelioration was rapid and intense, of the order of 7°C T_{max} once again, and then continued at a rate of perhaps as much as 1°C average annual temp per century (Lowe *et al* 1994). This rapid temperature change was not however uni-directional, as the ameliorating climate was briefly interrupted by a short cooling phase, the Pre-Boreal Oscillation (PBO).

During this brief spell, temperatures dropped by 1-3 °C over northern Europe, as identified from numerous pollen diagrams (Björck *et al* 1997, Hoek 1997), possibly c. 507-8 cm.

During the Pre-Boreal sea levels were also still rising so that by c. 10,000 ^{14}C yr BP the North sea shoreline was only 12 km to the north-east of Star Carr, although Britain was still attached to the continent (Figure 3.11). A succession of different herb and shrub communities formed in a response to these swift changes with an ameliorating climate suggested by the increasing values for meadow-sweet (*Filipendula*). The species present is assumed to be *F. ulmaria*, a thermophilious species often associated with shaded mires and tall herb communities. The presence of significant amounts of *Filipendula* suggest that summer temperatures can't have been less than 14°C (Huntley and Birks 1983). Gradually as the temperature changes and different communities respond to the changing climate, bare ground was colonised by grass and herb communities, followed gradually by birch, ferns and *Plantago media* which is a more thermophilious species than *P. maritima* (Clapham *et al* 1987).

This land based response was contemporary with the response of the aquatic taxa. *Typha latifolia* (Bulrush) one of the first colonisers of the inorganic substrate at the lake edges, was followed by *Equisetum* (horsetail) another emergent. A short lived peak of *Pediastrum,* a shallow lake algae, conceivably suggests lower lake levels in a time of dryness. Reduced humidity during the second half of the Loch Lomond Stadial has been proposed in several areas e.g. increased *Empetrum* is seen in Dutch pollen diagrams after 10,500 ^{14}C yr BP (Hoek 1997), and lower lake levels are seen in the Netherlands (Vandenberghe 1995). The subsequent emergence *of Myriophyllum c.f. spicatum* and *M. verticillatum, Potamogeton* and *T. angustifolia* attests to the increased productivity of the lake and formation of organic soils. A narrow band of vegetation was already established at the lake margins, consisting mostly *of Phragmites* with some *Typha latifolia* and other emergent species (see also Cloutman 1988b; Cloutman and Smith 1988; Day 1996a).

Despite the apparently inhospitable conditions there was a definite human presence within the Vale at some points during the Loch Lomond Stadial and pre-Boreal.

Radiocarbon dates from Site K at Seamer indicate humans were present between 10,200-11,300 ^{14}C yr BP (Schadla-Hall 1987b) and traces of 'long blade' technology have been identified at least one other site (Conneller 2000a). A flint flake associated with bones from at least three horses from muds underlying a gravel layer at Flixton 2 (Moore 1954), also denotes human activity in the Vale at c. 10,150 ^{14}C yr BP (OxA-6328) or even earlier (Walker and Godwin 1954).

The few faunal assemblages that have been assigned to the late-glacial in Britain, show an increase in reindeer, horse and virtual absence of woodland species (Tolan-Smith 1998). Due to the incredibly extreme nature of winter temperatures (Isarin *et al* 1998) it has been suggested that most activity within this Stadial period was limited to seasonal summer hunting forays from the continent, to exploit migrating herds of reindeer or horses. This assumption is supported by research by Conneller (2000a) who has actually determined that the 'long blade' tools were made of flint from what was the North Sea basin. She interprets this transport of foreign flint as being due to seasonal/sporadic visits to an unfamiliar place, whereby the visitors brought their own raw materials with them as they were venturing into an unknown environment.

3.12.3 Pre Holocene Charcoal

Throughout the whole of the Windermere Interstadial (GI-1a-e) and Loch Lomond Stadial (GS-1), charcoal concentrations are very high with peaks occurring during periods of more open environments. If some of the charcoal deposition during the early part of the Windermere Interstadial originated from human activity, it implies a very early human presence in the Vale. Such an early presence in the area is very probable as discussed above, however, the warmest periods when one would most expect a human presence in the area, correspond to the periods of lowest charcoal deposition in Profile D i.e., lows in charcoal concentrations, the number of charcoal pieces and the Charcoal:pollen ratio. As we are only just beginning to understand the complex and variable climatic conditions which prevailed at the time, charcoal deposition could actually be attributed to any one of several factors or combination of factors: human activity, climate or secondary deposits caused by erosion (see Edwards *et al* (2000)). Each of these factors will be considered separately in Chapter

Ten when the origins of the charcoal record (including pre-Holocene charcoal) are discussed in detail.

3.12.4 Early Mesolithic

Shortly after 10,000 ^{14}C yr BP there was another sudden and intense warming of the order of 7°C T_{max}, possibly within as little as 50 years or less (Dansgaard *et al* 1989; Taylor *et al* 1993; Alley *et al* 1993), so that by 9800 ^{14}C yr BP the temperatures in Britain were as warm or even warmer than those of today (Atkinson *et al* 1987). Once again there was a situation where the thermal climate was appropriate for the establishment and widespread growth of thermophilious deciduous woodland, but this did not happen. The biota was out of harmony with the climate and it took some time for it to approach an equilibrium with a wide variety of factors conspiring to delay the arrival of tree species and inhibit their ability to colonise this early post glacial landscape. In contrast, the response by human groups to this warming was rapid, and they were quick to move into the early postglacial environments (Tolan-Smith 1998).

Zone D-5 marks the beginning of the present post-glacial/Holocene. The re-establishment of open birch woodland with willow was presumably a response to the warming climate. As the postglacial progressed, open birch c.f. *B. pubescens* woodland spread rapidly across the landscape from the east (Birks 1989). At first it co-dominated with juniper scrub for a brief period early in the Holocene, but birch soon out competed the latter as woodland became fully established. Dates for this establishment vary but correlation with other profiles suggests it occurs at approx. 10,100-10,200 ^{14}C yr BP. The initial spread of birch has been dated to 10,120±180 ^{14}C yr at Roos Bog in Holderness (Beckett 1981) and 10,275±175 ^{14}C yr BP (Hv-17826) at Flixton AK87 (Innes 1994; Simmons *et al* submitted). Full birch woodland was well established by c. 9700 ^{14}C yr BP, although the birch pollen curve fluctuates sharply throughout the first millennium of the Holocene, which is attributed to climatic oscillations (see Lotter *et al* 1992).

In contrast to work by other authors, only a very limited amount of poplar pollen (≤1%) is found in the sediments of profile D (e.g. Day 1996a; Cloutman 1988b; Cloutman and Smith 1988; Mellars and Dark 1998). This is presumably due to poor pollen dispersal (Huntley and Birks 1983), as the pollen preservation is excellent and poplar pollen is present in other lake edge deposits (see page 91). The interpretation of poplar pollen is problematic (Huntley and Birks 1983) mostly due to its susceptibility to crumpling (Cushing 1967) and deterioration (Lichti-Federovich and Ritchie 1968). Levels of poplar pollen (up to 5%) at Star Carr infer that aspen was locally important in some areas, although this may not have been the case on the eastern side of the lake, as excellent grain preservation precludes the bias of deterioration. Poor pollen transport, migration lags, vegetation mosaics (a reflection of edaphic conditions and micro habitats) or crumpling and then concealment within the pollen slide may explain the lower levels of poplar on the eastern side of the lake. The local presence of aspen on the western edges of the lake is undisputed due to catkin and other macro remains (Day and Mellars 1994) which Day (1996a) interprets as evidence for carr woodland. Therefore, although the status of poplar along the eastern side of the lake is hard to establish due to taphonomic issues, it does seem likely to have been locally important or co-dominant on the moist or waterlogged lake side soils.

The status of pine within the catchment is also hard to determine as *Pinus* species are prolific pollen producers and the grains are easily transported over long distances (Huntley and Birks 1983). Therefore, the 10% pollen levels at D3 do not necessarily indicate local presence. Walker and Godwin (1954) found a single macro remain of *Pinus* at Star Carr. This suggests it either grew within the wider area of exploitation or was obtained from the continent where it was an important component of the woodland, e.g. The Netherlands (Bos and Janssen 1996), Denmark or Northern Germany (Walker 1995). If pine was indeed growing in the catchment it was likely to have been situated on the sandy esker soils.

Whilst birch formed the dominant tree canopy type during the early Mesolithic, light demanding shrubs and herbs were also able to co-exist alongside the male fern (*Dryopteris filix-mas*) in the understorey. The insubstantial leaf canopy of the birch

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trees would allow plenty of light to reach the forest floor (see Figure 3.12). Consequently, throughout the early Mesolithic, there continues to be a suite of ruderal and herb taxa, e.g. *Artemisia,* Compositae, *Rumex,* and Poaceae, indicative of a mosaic of communities in the woodland understorey. The open nature of the canopy is also indicated by the presence of woodland edge and scrub communities e.g. *Sorbus* and *Crataegus,* macro-remains of which have been found at Star Carr (Walker and Godwin 1954). Constant trampling along semi-permanent trackways or at watering areas and digging over by wild boars is also a probability. Wind throw gaps, natural tree wastage, beaver activity, ring-barking of trees by animals and infrequent natural fires would also contribute to the continuation of the dynamic vegetation mosaics.

Lake-edge productivity in the early Mesolithic is quite high with floating and emergent aquatics. *Typha latifolia* declined after the Pre-boreal, replaced by reeds (*Phragmites*) and sedges (e.g. *Cladium mariscus*) at the lake edges, with a persistent occurrence of *Thelypteris palustris* indicating its spread across the drier deposits. Lake Flixton is thought to have had a relatively stable hydrology at this time (R.T. Schadla-Hall *pers. com.*), but little is known about its exact dynamics. According to Walker and Godwin (1954:66) and Cloutman (1988a), during the early Mesolithic the water level stood about 22.5-24.0 m OD. However, low but fluctuating occurrences of the shallow lake alga *Pediastrum* and concentrations of several other aquatic species, may suggest oscillations between wetter and drier conditions throughout the early Mesolithic. This may also have been the case in the Netherlands during the first millennium of the Holocene (Bohncke and Vandenberghe 1991). Any longer-term fluctuations in lake levels due to climatic oscillations during the early Holocene, would have been superimposed on the seasonal variations in lake level. Huntley (1993) suggests there was higher seasonal variation in the early Holocene, thus, summer camps may well have been submerged in winter months, a factor which might well account for some of the preservation of the archaeological evidence.

Greater than background levels of charcoal (c. 150 x 10^{-5} cm^2 cm^{-3}), in zone D-5, indicate periods of human activity in the region at some distance, and compare well with the archaeological record. Domestic fires and/or deliberate burning of the vegetation can be envisaged, due to the evidence for archaeological activity and the

periodicity of the burns which is unlikely to be attributable to the climate (Chandler *et al* 1983; Rackham 1980). The low but discernible levels of charcoal are likely to be a result of charcoal dispersion far from its source (Clark 1988a) or due to low energy domestic fires in the vicinity, whose charcoal does not travel far (Bennett *et al* 1990b; Pitkänen *et al* 1999). In fact, if the charcoal deposition during the Windermere Interstadial and Loch Lomond Stadial is human in origin, then it infers that human settlers modified or subdued their fire activities in the early Mesolithic. The Upper Palaeolithic and early Mesolithic use of fire will be investigated further in Chapter Ten.

The top half of zone D-5 marks the arrival of hazel (*Corylus avellana*) into the region. In profile D there looks to be a sudden short lived hazel expansion to 5-20% TLP, before the real expansion a number of years later. The calcareous substrate appears to rule out the presence of *Myrica gale* and instead implies a low but consistent amount of hazel within the region. Huntley and Birks (1983) note that occasional low *Corylus* values (1-5%) occur in several late-glacial sites in Britain, but discount these as evidence for local presence due to the possibilities of distant transport or secondary contamination. However, in profile D at least, there is no indication of pre-Quaternary spores, and thus no substantial evidence that this pollen has derived from reworking of older sediments.

Day and Mellars (1994) dated the local arrival of hazel to c. 9400 ^{14}C yr BP (9385±115 ^{14}C yr BP) at the lake edges with a population expansion (>45% TLP) dated to c. 9000 ^{14}C yr BP (8940±90 ^{14}C yr BP). The rapid decline in birch and sudden rise in hazel to over 50% TLP in zone D-5d suggest pollen accumulation is slow, however no hiatus is thought to exist as other pollen taxa appear fairly continuous. This rapid increase in *Corylus* could be caused either by a sampling break, (two cores overlap at this point), or a slow down in marl deposition, as the stratigraphy remains unchanged. Sampling across the two core overlaps did not resolve the problem and thus a slow down or cessation in marl formation may be responsible. However comparison with the work of Day (1996a) demonstrates that if there is a break in sedimentation then it is short-term lasting for probably no more than 20-30 years.

These extremely rapid and early increases to high levels of hazel pollen are a striking feature of early Holocene diagrams from North western Europe. Human firing of the vegetation as a force behind this rise has been discussed at length following the initial paper by Smith (1970) and will be considered further in Chapter Eleven once more evidence has been collected.

3.12.5 Later Mesolithic

After c. 9000 ^{14}C yr BP the very high percentage values for hazel in zones D-6 and D-7 may indicate the canopy forming nature, rather than the understorey nature of the species at this time, but interpretations are hampered by lack of modern analogues (Rackham 1980). Pollen concentrations are extremely high, reflecting the high pollen productivity of this species. *Betula* c.f. *pubescens* has probably been replaced by *Corylus* in all but the dampest areas of the catchment. Here it is able to persist alongside *Salix*. This dense woodland canopy, caused a decrease in the diversity of the woodland herb layer, especially decreasing the population of woodland ferns, grasses and herbs which until then had formed a significant component of the groundflora of the early Mesolithic woodlands. This decrease in diversity is often cited as the reason why some form of woodland management was instigated by later Mesolithic peoples.

During zone D-6 elm (*Ulmus*) becomes a consistent member of the woodland canopy as the woodland starts to develop into mixed deciduous woodland with the establishment of oak (*Quercus*) rather a lot later c. 8000 ^{14}C yr BP. By c. 9000 ^{14}C yr BP, aspen has disappeared from the regional vegetation, out competed due to the warmer climate, increasing tree canopy and stabilised soils. The rational limit of elm is undated in this profile but occurs at approximately the same time as the massive *Corylus* expansion c. 9000 ^{14}C yr BP. *Quercus* is also present but at low frequencies in this zone. Its low values and delayed establishment may be attributable to the lack of suitable acidic and infertile soils required for its growth (Bennett 1989).

Low quantities of oak, elm and hazel are observable from the very beginning of the Holocene and sporadic occurrences occur even earlier. The presence of their pollen seems unlikely to be attributable solely to long distance transport, but instead may be explicable by small outlying populations in sheltered valley locations. An inability to

expand from these small populations until later in the Holocene would then be likely, due to competition from species more able to tolerate lower summer temperatures, in addition to edaphic constraints. The very early presence of these 'thermophilious' trees/shrubs is discussed in more detail in Chapter Eleven.

Throughout D-7 oak expanded, to become a significant woodland contributor on the acid or neutral soils, whilst willow (*Salix*) was able to maintain a very limited presence at the very edges of the lake. Hazel concentrations remained very high and elm populations were relatively stable. Later, the diversity of the mixed woodland continued to remain low throughout zone D-7 and hazel percentages decreased towards the top of the zone as oak and then alder started to replace it in some areas.

The areas of open water continued to contract as reeds and fen sedges encroached even further inwards into the lake. By the top of zone D7 aquatics such as *Nymphaea* and *Typha angustifolia* are persistently present, perhaps quite nearby. Pteropsida (monolete) undiff, most probably marsh fern (*Thelypteris palustris*), has become established throughout the catchment on the encroaching fen edge deposits. The shallowing of the lake in the near vicinity is shown by rising *Pediastrum* levels although the progressive decrease in water depth and extent probably also coincided with a period of lower lake levels. Tipping (1996) suggests there was a period of dry conditions at about c. 8000 ^{14}C yr BP on the continent, which would no doubt have facilitated the hydrosere development. There is no obvious palaeoecological evidence for the >2 °C cooling event at 7400 ^{14}C yr BP as previously identified by Alley *et al* (1997) and later by Klitgaard-Kristensen *et al* (1998).

The exact timing of the local establishment of alder within these woodlands, presumably *A. glutinosa*, is problematic (see Chapter Eleven). The radiocarbon date for the alder rise at Profile D is considered far too old, and has undoubtedly been affected by a hard water error. After all, the alder rise in Day's (1996a) profile is some 700 years younger, even though the core was taken from an area just over 1 km to the east (see Figure 3.1 earlier). However, once it had become established, alder carr was probably dominant around the lake edges, as indicated by the pollen values from profile D. The decreasing depth of the lake as shown by the change from marl

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to organic mud, and the increasing levels of *Pediastrum* are probably inextricably interlinked to the alder rise in this profile. As the alder population increases, it is to the detriment of hazel, although decreasing hazel values are also linked to a general increase in woodland diversity with ash *(Fraxinus)* and ivy *(Hedera)* consistently present.

A significant aspect in zone D-8 is the increase in charcoal concentrations, particularly macro pieces (>8800 μm^2) and a rise in the Charcoal:pollen ratio. It is suggested that this is a local causative factor affecting the composition of the vegetation, e.g. alder and hazel frequencies fluctuate and may be connected to charcoal and canopy disturbance. Repeated occurrences of secondary woodland indicators such as ash and ivy, in association with an increase in herb diversity, also infer woodland disturbance and an opening of the canopy in some areas. A human cause for the expansion in alder populations has been suggested by Smith (1970, 1984), and discussed in relation to the Vale of Pickering in Cloutman (1988b) and Day (1996a) and later in this thesis in Chapter Eleven. Studies by Hirons and Edwards (1990) and Edwards (1990) have deduced that burning and clearance appears to favour the spread of alder. Indeed, the Charcoal:pollen ratio in profile D does increase coeval with the start of the alder rise. There does also appear to be an increase in herb diversity, i.e. disturbance after the transition to alder carr, but there is no evidence for any contemporaneous increase, at this sample resolution.

There is also evidence in profile D, for local populations of alder for sometime prior to its expansion. This is particularly noticeable in the early Mesolithic (zone D-5b), where a phase of fine resolution pollen counts has identified a peak in alder early in the post-glacial. Further investigation is needed to see if this expansion of local alder populations occurs simultaneously with burning. Naturally, some early occurrences of alder pollen could reflect deposition by wind or erosion of pre-existing sediments, but the very constant inputs (often >1 grain) are unlikely to be explicable by the former and are not associated with clays or pre Quaternary spores. In fact Tallantire (1974:533) states that *"regional transport of alder pollen, producing pollen values >1% seems unlikely even in unforested areas, so that the timing of the local appearance of alder in any abundance should be relatively easily detectable in a pollen diagram"*. Therefore,

it is highly probable that there were some stands of alder within the region during the early Mesolithic. This issue is discussed further in Chapter Eleven.

The large increase in alder populations in Profile D is closely followed by the appearance of lime (*Tilia*) some 50 years later. Lime pollen is severely under-represented in the pollen record (Andersen 1970) and despite its low pollen percentages its contribution to the community is likely to have been fairly substantial on suitable soils such as the brown earths. Poplar (aspen) also returns as a pioneer species in the secondary woodland along with ash (*Fraxinus*). *Fraxinus* peaks at the top of zone D-8 after what appears to be a canopy disturbance. Herb totals and diversity have also increased throughout the zone, e.g. for Ranunculaceae, Compositae Lig. and Apiaceae, perhaps reflecting the woodland disturbance and the vicinity of the fen communities along the lake edges. The local hydrosere succession is clearly shown within the aquatic pollen record as *Nymphaea* and *Typha angustifolia* become locally established and *Pediastrum* values peak and then decline as the water becomes increasingly shallow. Such environments allow the flourishing of local fern populations on the surface of the encroaching fenland.

Charcoal peaks coincident with vegetation disturbances are more frequent and of greater scale in the Later Mesolithic than in the early Mesolithic. The vegetation impacts in sequence D suggest that the proposed human impacts are now large enough to be regionally detectable. However, it is not until the alder rise that the charcoal deposition exceeds levels found from the early Windermere Interstadial deposits.

3.12.6 *The Elm Decline?*

The beginning of zone D-9 may document the first evidence for the elm decline from the region, but requires further research for clarification. Zone D-9 appears to represent a phase of intensive vegetation disturbance, resulting in the decline of several tree species including elm. It also shows the creation of open areas of grassland, inferred from the presence of a number of dry land pollen grains including *Centaurea nigra* and *Plantago lanceolata*. A similar but undated, phase of vegetation disturbance accompanies the elm decline at Roos Bog and Hornsea Mere (Beckett 1981), while the elm decline has been dated to 5099±50 ^{14}C yr BP at Gransmoor Quarry, northern

Holderness (Beckett 1975). The date obtained for the top of the profile D is 5740±50 ^{14}C yr BP (Beta-104479), a date which is potentially too old to represent the 'classical' elm decline. However, this old date may in part, be attributable to the large stratigraphic width of the radiocarbon sample.

The elm decline and associated creation of more open environments is a characteristic but not entirely synchronous marker over much of north-west Europe. The majority of radiocarbon-dates for the elm decline tend to cluster a couple of centuries either side of 5000 ^{14}C yr BP, though some are notably earlier or later e.g. 5690±45 ^{14}C yr BP in profile 9 and 3490±45 ^{14}C yr BP in profile 6 at North Gill (Simmons and Innes 1996b). If the date of 5740±50 ^{14}C yr BP for zone D-9 is actually incorrect, this would mean the sediments in profile D are much younger than indicated and could bring the dating of the elm decline nearer to the expected dating range. According to Huntley and Birks (1983), *Fraxinus* is estimated to have reached Northern Yorkshire just before c. 6000 ^{14}C yr BP at values of 1-2% (Birks 1989). This actually occurs well before the start of zone D-9 and therefore the top of profile D may be more likely to date to c. 5300 ^{14}C yr BP.

The Elm Decline has been discussed at length in the literature e.g. Huntley and Birks (1983); Rackham (1980); Regnéll *et al* (1995) and Simmons (1996), with a general consensus that elm pollen decreases due to the combined effects of outbreaks of elm disease and opportunistic and repeated use of areas by humans. In D-9 there is a 75% decline in *Ulmus* percentages over the space of one sample (4 cm) or c. 50-60 years deposition. This is of the same order of magnitude as the declines at Ågerods Mosse, southern Sweden (Skög and Regnéll 1995) and Diss Mere, England (Peglar 1993), although the latter declines occurred over <40 years and in 6-7 years respectively. The timespan for the elm decline here is most likely an artefact of the sampling interval, and further finer resolution sampling would reveal a much more abrupt change. The reduction in tree cover is not monospecific as it also affects *Quercus* and *Alnus,* while *Corylus* fluctuates rapidly. Disturbance of the woodland canopy therefore occurs at the lake edge as well as on the fertile moist soils and the poorer dry soils and is accompanied by an increase in light demanding shrubs and pioneer trees e.g. elder

(*Sambucus*) and poplar. This suggests that human agency was a factor in the decline of elm (however irreversible) at this time.

The start of the Neolithic in Britain has been dated on archaeological grounds to approximately 5300 ^{14}C yr BP (Williams, E. 1989) and hence a fall in elm pollen is often conveniently taken to denote the start of the Neolithic in pollen diagrams. It should however be noted that the Mesolithic/Neolithic boundary is not a fixed one (see Edwards 1988; Simmons 1996:150-3). It is clear that small scale cultivation may have taken place at a very early date in some areas of Britain e.g. by 5820±95 ^{14}C yr BP at Soyland Moor (Williams, C. 1985), 520 years before the first group of attested Neolithic dates given by Williams, E. (1989). Thus, a date of 5740±50 ^{14}C yr BP for the elm decline in the Vale of Pickering, with its intensive history of human occupation, cannot be ruled out. However, no cereal pollen has been found in the deposits at D, except a single Poaceae grain >40 µm^2 at 248 cm. Consequently, even if the classical elm decline is shown in zone D-9, no inferences about the start of Neolithic agriculture in the Vale can be made.

Another option is that the first fall in elm pollen in D-9 is merely a pre-elm disturbance phase. It has been noted by Simmons and Innes (1988) that there is often an increased frequency of disturbance towards the 'classical' elm decline. Charcoal deposition is also fairly high in D-9 which is in contrast to the general trend in palynological diagrams whereby a fire suppression after the elm decline is often observed, e.g. Edwards 1988, 1990; Edwards and McIntosh 1988; Robinson and Dickson 1988; Simmons and Innes 1981, although not always: see Tipping and Milburn 2000 and Parker *et al* 2002). Therefore, due to the termination of the elm curve in D-9 and the uncertainty of dating, zone D-9 may in fact record a pre-elm decline clearance, like the ones seen at Bökeberg III , Sweden (Regnéll *et al* 1995) and at North Gill (Simmons and Innes 1996b).

The high percentages of Poaceae and Cyperaceae in zone D-9 may be attributed to the influx of pollen from the local hydrosere succession, also associated with the high *Filipendula* levels (perhaps *F. ulmaria*.) It is unlikely that the environment was as open as suggested by the pollen diagram. Nonetheless, some fairly significant

woodland disturbance had taken place and some areas of grassland must have been created, allowing growth of *Aster* types, *Centaurea nigra* and *Plantago lanceolata*. The high Pteropsida (monolete) undiff. and Cyperaceae concentrations are a feature of many of the pollen profiles from the area (e.g. Walker and Godwin 1954) . It appears that *in situ* fen develops, producing an environment non-conducive to organic preservation. These conditions persist until anaerobic waterlogged conditions are re-established following a rise in groundwater.

In part, the tree decline is attributable to lake edge encroachment and the drowning out of woodland taxa by local pollen inputs especially Cyperaceae and Poaceae (c.f. *Phragmites*), although some local pasture/dry land input is also observable e.g. *Centaurea nigra* and Compositae (Lig.). However, the observed changes cannot be explained by this alone. Tree concentrations decline significantly at the top of the profile contemporary with a drop in total pollen concentration. This could be attributable to the augmenting deterioration of the peat within the Vale. *Ulmus* is known to be one of the more fragile of the pollen grains (Havinga 1964) and most likely to be under-represented during poor preservation conditions. The occurrence of *Populus* pollen does however suggest that preservation levels are not too detrimental. Alternatively the general decrease in the percentage values may be due to high pollen concentrations of Cyperaceae and Poaceae, and the decline in total concentration values may be a consequence of the sediment accumulation process. The organic mud in D-9 may have accumulated faster than the mud below it. Without the presence of datable macrofossils it is impossible to determine the rate of deposition of the sediments, which is likely to have varied considerably through time.

Thus, in zone D-9 a number of complex processes and vegetation changes are being reflected in the pollen profile concurrently. Dry land disturbance including some elm clearance or perhaps branch lopping does occur, enabling soil enrichment and scrub growth e.g. *Sambucus* and *Crataegus*. This also resulted in the formation of significant patches of open land within a less well forested environment which permitted the establishment of grassland species, e.g. *Centaurea nigra,* and open land weeds, e.g. *Pteridium*. There is also some disturbance of the marginal waterlogged deposits

resulting in an increase in lake edge diversity and the growth of *Populus, Silene* sp, *Rubiaceae, Succisa* and *Ophioglossum.*

3.13 Comparison of Profile D with profiles from Star Carr

3.13.1 Differences and similarities between the charcoal records

In profile D, charcoal is very abundant in the pre-Holocene record (zones D-1 to D-4), as the climate ameliorates following the deglaciation of the area. Charcoal concentrations are particularly high until the beginning of Zone D-2a. This is in contrast to the negligible amounts of charcoal from Star Carr during the pre-Holocene, except during zone S3-a (Day 1996a), which is potentially equivalent to zone D-2c (possibly Greenland Interstadial-1c). Thus the pre-Holocene charcoal records from the two sites appear to be markedly different, despite the fact that they are only c. 1 km apart.

During the Pre-Boreal both charcoal records appear to be in agreement, as charcoal is relatively high at the top of zone D-4 in profile D and also in zone S-4 from Star Carr (Day 1996a). This period of charcoal deposition may correlate with phases of 'long blade' activity from various sites around the lake, e.g. Star Carr and Site L. Slightly later, during the early Mesolithic, profile D shows at least three phases of charcoal activity in the region in contrast to the single phase of activity that is visible in Day's (1996a) core.

The spatial extent and intensity of the lake edge fires at Star Carr are presently unknown (Day 1993; Day and Mellars 1994; Mellars and Dark 1998). However, the localised deposition of micro and macroscopic charcoal between Trench A and Clark's site (Mellars and Dark 1998, Chapter One), suggest a very localised deposition of charcoal during fire events. As a result, the levels of charcoal within the regional profile (D) can be considered to represent the background levels of charcoal during this particular time period, and can be applied to assessments of fire activity at the lake edge sites. In later chapters it may be possible to link these early Mesolithic charcoal inputs to specific phases of human occupation at the lake edges.

Towards the end of the early Mesolithic, charcoal deposition peaks at the end of zone D-5, just prior to the *Corylus* rise. This horizon also correlates with Mesolithic activity at Star Carr (Dark 1998). Charcoal deposition in both cores increases significantly at the start of the *Alnus* rise.

In summary, in some ways the charcoal record from profile D appears to be markedly different to the results of Day (1996a), e.g. during the pre-Holocene, but sometimes it is in agreement. In this present study, charcoal particle size classification has been used in order to demonstrate the nearness of the fire event (Tolonen 1983), a method which is potentially more informative for analyses of the shallow archaeological deposits (Rhodes 1996, Pitkänen *et al* 1999). Day (1996a), on the other hand, used the point count method of Clark (1982). Differences between the two charcoal methods have been summarised by Patterson *et al* (1987), but mainly concern the ability of the size class method to pick up times of very low charcoal influx. However, there will also be a factor difference between the representation of area/dry weight (Day 1996a) and area/volume (here), although the general pattern should still stay the same. From the results it can be inferred that either the two methods are sometimes incomparable, or the fire history was significantly different along the eastern side of the lake. However, much of the difference may be attributed to different representation of the data, particularly axis scales, sensitivity, and difficulty of determining the level of background noise (assumed to be 50-100 $\times 10^{-5}$ cm^2 cm^{-3}). Studies such as this, highlight the need for more methodological charcoal research to determine the differences between methodologies, data representation and levels of background noise, although see Clark *et al* (1996).

3.13.2 *Differences between the vegetation records*

Throughout the Windermere Interstadial (GI-1a-e, zones D-1 to D-3), the vegetation sequence broadly follows the same vegetational and climatic patterns of the work by Day (1996a). The only exceptions being the slightly inflated arboreal percentages at D during the Windermere Interstadial and the occurrence of only one pre late-glacial climatic deterioration, although a second is possible at c. 560 cm but hampered by poor sample resolution. Profile D was taken more towards the centre of the lake than Day's (1996a) profile and the slightly higher birch values are attributed to a more regional and

less local origin of the pollen rain. In addition, the lower percentages of juniper in profile D-2a compared to Day (1996a) must be a feature of the poor dispersal of the pollen grains and hence the distance from the lake side.

In contrast to Day's (1996a) profile, which registers extensive sedimentation during the Loch Lomond Stadial, sedimentation in the profile D is relatively truncated during this period. This is attributed to its location near the centre of the former lake, as the 'unsorted solifluction layer' identified by Walker and Godwin (1954:36), was described as thinning towards the centre of the lake. The central location of profile D may also partly explain why the profile has a lower rate of sediment accumulation.

Day (1996a) also records significant and frequent levels of aspen pollen (up to 5%) in her early Holocene deposits, but this latter episode is not seen clearly at D, although sporadic grains (≤1%) do occur. The higher levels at Star Carr may reflect the slightly more local aspect of Day's profile indicated by the higher occurrence of disturbed and open land taxa e.g. goosefoot and rosebay willow-herb, and the slightly lower tree percentages. More significantly, aspen levels at Star Carr may be inflated due to local disturbances by humans or beavers (e.g. Ralska-Jasieniczowa and Van Geel 1992). Day (1993) suggested that soil disturbance by humans created areas of bare soil which provided suitable areas for birch and aspen seedling establishment.

By comparing the two periods of fine resolution sampling, see Figure 3.13, it can be seen that both profiles appear to represent the same broad vegetational periods. In fact, both diagrams appear to be fairly similar, i.e. individual species appear to fluctuate by roughly the same amount at Star Carr and at location D3. Sometimes one can even imagine that the curves are almost identical. This serves to illustrate the difficulties of comparing two similar diagrams merely by eye.

The fact that the two fine resolution phases appear to cover the same broad time period has important implications for the charcoal record. It serves to demonstrate the local aspect of the charcoal rain during the early Mesolithic, as charcoal peaks which occur at Star Carr, do not show up within profile D, c. 1 km away. However, it should be borne in mind that the same argument may not be applicable during the

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Upper Palaeolithic and/or later Mesolithic periods as air or water currents may have changed markedly between different time periods.

Despite the apparent similarity between the profiles, there are still a few marked differences e.g. the lower levels of poplar pollen in Profile D as discussed earlier, and the much higher levels of *Alnus* pollen. Further investigation is needed to see if this expansion of local alder populations occurs simultaneously with burning. The early occurrence of alder is discussed in more detail in Chapter Eleven.

Finally, if the fluctuations in the *betula* pollen curves in Profile D and Day's (1996a) profile are assumed to be mainly responding to regional changes in the climate, then comparison of the two curves should show them to be broadly similar, and this is found too be largely true. A small section of the core was selected by eye for close interval sampling, from a section that was thought to be analogous and contemporary to the human occupation at Star Carr. However, the period of close interval sampling in profile D appears to occur at an earlier point in the male fern curve than it does on Day's (1996a) diagram. This could be for three reasons:

i.   the period of sampling is contemporary with the occupation at Star Carr but both profiles have markedly-different pollen source areas.

ii.   the period of sampling is contemporary with the occupation at Star Carr but the appearance of male fern was asynchronous within the Vale.

iii. the fine resolution phase in Profile D is not contemporary with the occupation at Star Carr, in fact it relates to an earlier time-period.

The first explanation (i above) cannot be entirely discounted, but is thought to be unlikely due to the large distances from the shoreline (400 m and 700 m respectively). The water depth at both locations would also have ensured that the pollen had a regional composition (Chapter Two). The relatively small perimeter of the lake (c. 13 km), and the near synchronous appearance of *Corylus* and *Betula* within the Vale (Day 1996a; Dark 1998; Beckett 1981; Innes 1994), means that the second explanation (ii above) also appears unlikely. Consequently, iii (above) appears to be the most likely explanation. In Chapter Ten this hypothesis is used to create a relative dating chronology for the different periods of human settlement in the Vale, due to the absence of absolute radiocarbon dates (see also Chapter Two).

In the later Mesolithic in profile D (zones D-6 and D-7), oak values remain low for about 1000 years after the establishment of elm. However the establishment of oak at profile D is still much earlier than at Star Carr (Day 1996a). The sudden increase in oak at Star Carr was attributed to a hiatus of c. 800 years (Day 1996a). In contrast, the sequence at D3 is believed to be continuous at this point, and may indicate that the hiatus in Day's profile was equivalent to most of zone D-6, or around 890 years at a rate of 12.4 cm yr^{-1}. (see accumulation rates in Section 3.8, earlier). Any variations in oak establishment are likely to be related to local soil conditions (see below).

It is estimated that profile D contains about 56 cm more sedimentation than Day's (1996a) sequence, based on the *Corylus* curve which appears to have a regional representation at the lake centre at c. 9000 ^{14}C yr BP. If sedimentation occurred at a rate of c. 12.3 –16.2 yr cm^{-1} (see Section 3.8, previously), then this equates to c. 695-907 years of deposition, and implies a date of c. 5820-5610 ^{14}C yr BP for the top of profile D. It is therefore probable that the date of 5740±50 ^{14}C yr BP (Beta-104479) for the top of profile D, is actually fairly representative of the age of the top of the profile. Consequently, the elm decline in zone D-9 is uncharacteristically early, perhaps too early to be considered as a 'classical' elm decline, although the elm decline at North Gill Profile 9 occurs only a little later at 5595/5690±45 ^{14}C yr BP (Simmons and Innes 1996b). North Gill is also an upland site and the elm decline in the uplands is often considered to have taken place some time later than in the lowlands (Simmons 1996).

3.14 Comparison of Profile D with profiles from the rest of the Vale

Comparisons of profile D with work undertaken by Walker and Godwin (1954), show that the profiles are all very similar, probably as a consequence of their deep water locations. (Comparisons were made using Godwin's convention of calculating pollen as a % total tree pollen, excluding *Corylus* and discounting *Juniperus* entirely).

Profile D is one of a number of profiles that contain sediments dating to the Late Glacial Stadial and Windermere Interstadial, as far back as c. 13,000 ^{14}C yr BP, e.g. QAA, PCC, (Cummins 2000b, 2001); (Day 1996a); DB1, A16, (Walker and Godwin

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1954). In contrast to Day's (1996a) profile, both QAA and PCC provide evidence for the widespread occurrence of pre-Holocene fires especially between c. 12,500-12,000 ^{14}C yr BP. Slight differences in the timing of these temporally discrete fire events suggest that the fires were sometimes confined to selected parts of the catchment, and were not always regional and widespread in occurrence. These pre-Holocene lake-edge profiles are also able to provide a more detailed picture of the vegetation during these cold stadial events. They show that there were at least three climatic oscillations prior to the late-glacial and that pine was definitely absent from the southern lake edge.

In the Pre-Boreal, a short lived peak of *Pediastrum* in profile D, conceivably suggests lower lake levels in a time of dryness. This proposal is supported by the observations of Cloutman (1988a) and Walker and Godwin (1954:36). Conversely, research at PCC and QAA along the southern edge of the lake (Cummins 2000b; 2001), suggests there was a period of increased water level during the early part of the Late Glacial Stadial. Similar observations have also been made at other sites in north-west Europe (van Geel *et al* 1989; Hammarlund *et al* 1999; Bos and Jansen 1996)

There is no evidence from profile D for any other marked fluctuations in lake levels during the Mesolithic as suggested by Cloutman (1988b) and Walker and Godwin (1954). Profile D merely shows the unidirectional continuation of the hydrosere, although small fluctuations in *Pediastrum* and by inference lake levels, do occur. Water level fluctuations will be discussed in detail later in Chapter Eleven, once more evidence has been accumulated.

Towards the end of the early Mesolithic, a charcoal peak, just prior to the *Corylus* rise occurs at more then one location in addition to Profile D, e.g. Star Carr (Walker and Godwin 1954; Dark 1998), QAA (Cummins 2001) and VPCG (Innes 1994). At Moore's site 9, VPCG (Innes 1994), the hazel rise actually coincides with a thick charcoal layer which correlates to an increase in ruderals within the pollen diagram e.g. *Plantago lanceolata* (ribwort plantain) and other weeds. Beneath the charcoal layer early Mesolithic flints are stratified within the peat.

In the later Mesolithic, oak values in profile D (zones D-6 and D-7), remain low for about 1000 years after the establishment of elm, which is in contrast to other profiles (e.g. Flixton AK87, DB1), where oak values follow the normal pattern for the wider region. It is likely that this regional variation in oak establishment, is attributable to a lack of, or delayed formation of suitable soils for its growth i.e., acid or neutral free draining soils for *Q. petraea* or heavy clayey soils for *Q. robur* (Bennett 1989). This may have been the case at Seamer Carr (Cloutman 1988b) where oak does not expand until the alder rise, although local oak expansions undoubtedly occurred earlier where conditions were favourable. Alternatively, oak may have been in direct competition with pine at Seamer and therefore its expansion was prevented until conditions became more favourable.

Another significant difference occurs at Flixton Island, where Innes' (1994) profile AK87 infers local pine dominance in some areas. This is in stark contrast to the regional profile, which suggests pine is a very insignificant member of the Mesolithic woodland.

In profile D, at the current sample resolution, there is no evidence to suggest any large scale disturbance of the vegetation at the time of the alder rise, despite the occurrence of vast amounts of charcoal. Whereas at Seamer Carr (Cloutman 1988b) the expansion of alder is often associated with a 'black layer' in the peat and Day (1996a) also records high levels of charcoal in her zone equivalent. Macro charcoal fossils from her profile were identified to reed (*Phragmites*), willow and alder, suggesting local *in situ* burning of the wetland vegetation. There is also an increase in the abundance of ruderals at the transition to alder carr at AK87 (Innes 1994), with creation of open areas and the appearance of ribwort plantain (*Plantago lanceolata)* and a large peak in bracken (*Pteridium)*. In addition, the pollen diagram from E77, East Island, Seamer Carr (Cloutman 1988b), shows that the dry land vegetation and soils and perhaps the marginal water deposits were disturbed at levels coeval with a rise in alder. Small amounts of *Melampyrum* (cow-wheat) also occur. Cow-wheat is generally associated with woodland clearance (Iversen 1949; Simmons 1969) and burning (Mamakova 1968; Tinsley 1976 and Cloutman 1983).

Finally, at D3 some fairly significant woodland disturbance took place around the time of the elm decline. This disturbance created some fairly extensive areas of grassland and allowed the growth of *Aster* types, *Centaurea nigra* and *Plantago lanceolata*. A similar phase of vegetation disturbance took place at Flixton AK87 (Innes 1994) at c. 5300±85 ^{14}C yr BP (Hv-17821).

3.15 Quantifying the Variability in the Regional Pollen Diagram

Modifications to the vegetation as a result of human activities have not yet been detected at a regional level during the early Mesolithic. Consequently the regional core (D3) should provide a fairly accurate picture of the 'natural background' vegetation, against which the archaeologically linked profiles can be compared and contrasted.

Nonetheless, before one can assess the detailed differences between the 'natural' vegetation and the potentially anthropogenically affected profiles from the lake edge, it is first necessary to investigate the precision of the pollen data. Many palynologists try to explain differences within and between profiles in terms of local pollen representation or human impacts, without first considering the accuracy of the data they are using.

In this study the fluctuations or variance in the regional pollen percentages during the early Mesolithic are caused by two main factors. These are:

    i)   inherent variability in the pollen data (IV)

    ii)   'background' variations in pollen output caused by climate, seasonal fluctuations in pollen output, soil and competitive interactions. In future this will be referred to as 'background variation' (BV).

Both of these factors need to be calculated and considered for the regional profile, prior to analyses of human impact at the lake edges. IV and BV will be considered separately in the following sections:

3.15.1 Internal Sample Variability (IV) - Pollen Confidence Limits

The observed fluctuations between different levels in a pollen diagram, may be caused by inbuilt variability in the percentage pollen counts. This is a result of the size of the pollen sum used (Mossiman 1965; Birks and Gordon 1985; Faegri *et al* 1989). Pollen confidence limits can be calculated for each species in a pollen profile and used to determine the uncertainty and actual variation associated with the pollen percentage counts on each level. This in turn helps to assess the true variability between different levels on the same diagram, as well as helping to assess and explain the differences between pollen diagrams.

Figures 3.14-3.15 show the 0.95 confidence limits (95% confidence intervals), for some of the major taxa in the Regional Profile (D3). Figure 3.14 shows the confidence limits across the entire sequence and Figure 3.15 just relates to zone D-5 (the early Mesolithic). The 95% confidence limits have been computed and generated using PSIMPOLL (version 4.01) (Maher 1972; Bennett 1992, 1994, 2002). This calculates and plots 95% of the expected variations in the pollen counts, using two standard deviations from the mean (2σ). The confidence limits help to show where significant changes in the pollen spectra occur, as opposed to where minor fluctuations arise and the pollen confidence intervals overlap. This then allows the identification of statistically significant changes in the pollen curves which, (in the case of D3), may be the result of background variations (BV) in the pollen data, rather than inherent variability in the data itself (IV).

Naturally, the degree of within sample variability will depend on the species under consideration and the pollen sum used. Consequently each of the major taxa should be treated individually in order to elucidate the nature of the pollen representivity in more detail.

3.15.2 Background Variability in Pollen Production

In addition to the X % inherent variability in the data of each species defined by the 0.95 pollen confidence limits, there is also additional variability in the pollen data in profile D3, (i.e. the sections of Figure 3.14 and 3.15 where the confidence intervals do not overlap). As the pollen from D3 represents the 'natural' vegetation, then these

variations must be explained by background variability (BV) i.e., natural factors such as; climate, seasonal variations or soil related factors.

Figure 3.16a shows the *Betula* pollen curve during the early Mesolithic (zone D-5). The 95% confidence limits have been plotted on either side of the pollen diagram. From the diagram it can be seen that at only 2 points in time (marked A and B), do the pollen variations clearly exceed the 0.95 confidence intervals of the preceding and proceeding samples. The *Betula* pollen changes at A and B must therefore be a result of background variability. Point A at a depth of 470 cm exceeds the 0.95 confidence limits by +4.56% to +8.75% (dependant on the values of the preceding and proceeding samples). In contrast, practically the whole of B (486.2-492.0 cm i.e., the fine resolution sampling section), appears to exceed the confidence limits on either side of it by around −7% to -12%. It would then be logical to say that climatic variability during the early Mesolithic may account for an additional +4.56% to +8.75% and −7% to -12% of the variation in *Betula* pollen outputs at the lake centre, over and above those caused by inherent sample variability.

In the regional profile, the BV can therefore be defined as the total variance of the data (E) minus the IV i.e., BV=E-IV.

However, if section B is considered in more detail (see Figure 3.16b) it can be seen that only some and not all of the samples fall outside of the confidence limits of samples 492 and 486 cm. Within this short section of the profile there is obviously a great deal of internal sample variability as well as background variability occurring. It can also be seen that, the degree of background variability in the data is dependant on the sampling resolution undertaken and the 'time window' used to observe the data. This means that fine resolution sections of the core need to be considered separately and the 'time window' used for calculations will also need to be kept constant to ensure a standardised approach.

As with the pollen confidence intervals, it is necessary to consider the BV of each species on an individual basis.

3.15.3 Application to the lake edge profiles

Only after the inherent sample variability and the limits of background variability have been defined in the regional vegetation, is it possible to look for human impacts on the vegetation at the lake edge. Discerning the confidence limits of the regional pollen data in D3, and ascribing the remaining variation to background factors is fairly straightforward, especially as the pollen from D3 is assumed to represent the 'natural' vegetation. However, at the lake edges there will potentially be another factor to take into consideration, that of human impact on the vegetation (HI).

In this case, the total variance in the pollen data (E) will be defined as BV+IV+HI (i.e., E= BV+IV+HI). Isolating human impact from the other factors is not straight forward. If a profile comes from an archaeologically related area, how does one know which changes are caused by background variations and which changes are caused by human activity? And at what point do these human changes start or finish? At what point can the vegetation be considered as being in its natural background state? Charcoal analysis can provide an indication of certain periods of human activity, but the time period of occupation is not necessarily delimited by the charcoal peaks and the absence of charcoal does not necessarily preclude human activity.

Instead of merely relying on subjective assessments of the data, this thesis attempts to approach this problem from a statistical viewpoint (for the early Mesolithic only). In order to do this several assumptions have been made. These are:

i) In D3 during the early Mesolithic (500-466 cm) the pollen at the lake centre reflects the natural vegetation and there is no detectable human influence on the vegetation. D3 then provides the baseline 'natural' pollen values.

ii) Under natural conditions the establishment of each plant species follows a trend during the early Mesolithic e.g. there is an upward trend in *Betula* as it migrates into areas of open land, whereas grass follows a downward trend as it is being displaced by *Betula* and shrubs.

iii) The trend in each species can be approximated using a regression line. Linear regression lines are used in this instance, however it is appreciated

that more complex regression statistics could achieve a better fit for the data.

iv) The pollen confidence limits (IV) can be plotted on either side of this trend by using 2 standard deviations of the pollen data (derived from Psimpoll).

v) In the regional profile the total variance E= IV+BV. This can be defined as $\sqrt{S_1^2 + S_2^2}$, where S_1 is the pollen confidence interval (to 2 σ) and S_2 is the variance around the mean of the regression line.

These assumptions have been applied to the *Betula* curve in the regional profile (Figure 3.17a). It can be seen that most of the fluctuations in the *Betula* pollen diagram can be explained by the internal sample variability (IV). All the remaining variations in the *Betula* pollen data (±5-7%) must then be attributable to background variations (BV) and the effects of pollen percentage changes caused by changes in the percentage of another species.

The regression line or trendline in the data will of course vary according to the distance over which the trend is taken. Figure 3.18a shows the regression line that is drawn when just considering the fine resolution samples between 486-492 cm. In this case the mean IV over this sample range is ±4.24% (ranging from ±3.75-5.2%), and the remaining background variability (BV) is therefore ±3.75-4.75%. In conclusion, over the long term (the whole of zone D-5), BV accounts for ±5-7% of the variation in *Betula* pollen data, over and above the in-built sample variability in the pollen percentage data. In contrast, over short time-periods BV only accounts for ±3.75-4.75% of the variation.

Having defined the background variability in at least one of the major species (*Betula*), these methods can now also be applied to each of the lake edge profiles in order to determine the intra and inter-site variability in the data. In order to apply these statistical analyses to the lake edges two further assumptions must be made:

vi) The BV at the lake edges is a proportion of the BV at the lake centre. As the BV is specific to an individual species, the proportion can be calculated from the relative pollen percentages.

vii) A zone at the lake centre is taken to be the same duration as a zone at the lake edge. This means that the regression lines will be taken over the same time period or duration i.e. zone-5, the early Mesolithic. (The zones are identified using CONISS as a standard analytical procedure for each pollen site. The CONISS zones define periods of similarity in the data and thus one can be sure that like is being compared with like. A smaller 'time window' will be applied to periods of fine resolution sampling, where the short time interval requires a totally different regression line and where background variability appears to be less marked. (This is acceptable if the fine resolution samples equate to similar time intervals).

Using these assumptions it may be possible to isolate periods of human impact on the vegetation within the archaeological profiles because:

- The IV for individual species at the lake edges can be calculated using 95% confidence limits derived from PSIMPOLL

- The BV has already been calculated for the regional profile.

- The human impact will therefore be any fluctuation that exceeds the combined variance of IV+BV.

Table 3.4 and Figures 3.17-3.18 a-f show the IV and BV values for various species at the lake centre during the early Mesolithic zone D-5.

In the succeeding chapters, individual species assessments for IV will be undertaken for each of the lake edge profiles and combined with the appropriate value for BV. Species assessments will be completed on an 'as needs' basis as it is likely that only a few major species will show any possibility of human impact. (To analyse over 100 taxa from seven different sites without first considering if they are applicable would be a very arduous task indeed).

It will then be possible to apply a three stage test for human impact.

i)   by conventional analyses

ii) using pollen confidence limits

iii) using the combined variance of IV+BV.

During conventional analyses of human impact, an increase in open ground taxa and disturbance indicators such as *Plantago lanceolata*, and *Urtica* is often taken as indicating the presence of human activities. However, within this present study a number of these species which have similar ecological niches, will not be considered in the statistical discussion, because their levels of occurrence are too low to allow statistical interpretation and their 95% confidence limits do not allow their fluctuations to be separated statistically.

3.16 Chapter Three -Summary

The main points from this chapter can be summarised as:

- Figures 3.2-3.4 show the 'natural', climatically produced vegetation that prevailed in the Vale during the period c. 13,000 –5,000 ^{14}C yr BP, and thus the type of vegetation that can be expected to be found at the lake edges. The type of climate and environment that would have faced these early hunter-gatherers is described in Section 3.12.

- Figures 3.2-3.4 also show the chronology of events and sequence of vegetation changes, against which the lake edge profiles can be correlated and compared (Chapters Four-Eight).

- Figure 3.5 shows the 'regional' or background levels of charcoal that were being deposited over the lake during different chronological periods i.e.:

  LPAZ D-1= $\leq$ 300 x10^{-5} cm^2 cm^{-3} ; D-2= $\leq$ 175 x10^{-5} cm^2 cm^{-3} ; D-3= $\leq$ 125 x10^{-5} cm^2 cm^{-3}; D-4= $\leq$ 200 x10^{-5} cm^2 cm^{-3} ; D-5 = 150 x10^{-5} cm^2 cm^{-3}; D6= 150 x10^{-5} cm^2 cm^{-3}; D-7= 200 x10^{-5} cm^2 cm^{-3};.D-8= 400 x10^{-5} cm^2 cm^{-3}; D-9= 250 x10^{-5} cm^2 cm^{-3}.

  Any charcoal levels from similar zones at the lake edges will need to exceed these thresholds before they can be considered a charcoal 'peak'.

- The identification of pre-Holocene charcoal demonstrates the possible presence of pre-Mesolithic cultures in the Vale of Pickering.

- Section 3.15 demonstrates that some of the fluctuations in a pollen profile can explained by the inherent variability within a single pollen sample. This section defines the 95% confidence limits of the pollen counts from the Regional Profile e.g. variations attributable to internal sample variability (IV). Table 3.4, Figures 3.17a-f and 3,18a-f show the calculated IV values for a range of species at the lake centre.

- Section 3.13 also demonstrates the degree of background variability (BV) in pollen deposition over different periods of time, throughout the profile. e.g. variations in *Betula* during zone D-5 have been shown to be in the region of ±9-11% at the lake centre. Of this value, ±4% of this can be explained by 'internal variation' in the sample. The remaining ±5-7% must be attributable to background variations. Figures 3.17a-f and Table 3.4 show the BV calculations for a range of taxa from the lake centre.

- Shorter-term variations (over c. 200 ^{14}C years) in pollen output also occur, but are dependant on sample resolution. These variations tend to be smaller in magnitude. Figures 3.18a-f and Table 3.4 show the short-term variation in BV and IV for selected species.

- In order to 'confidently' detect human induced changes, any pollen changes at the lake edge will need to be greater than the background variations in D3. The degree of variation depends on the species involved and the time frame of analysis e.g. climatic variations in *Betula* during zone D-5 have been shown to be in the region of +/- 3.75-7% at the lake centre, depending on the time frame under consideration.

- The degree of background variability can be 'normalised' using proportions and applied to the lake profiles in later chapters. This will help identify/isolate periods when the vegetation change is greater than the natural variability (including internal variability) and thus identify what are potentially periods of human activity. Periods of human impact are most likely to be associated with charcoal peaks. Significant pollen variations without the additional information provided by charcoal cannot be

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confidently linked to human activity, although it is still a possibility. Vice versa, periods of inflated charcoal deposition do not necessarily mean humans altered the vegetation in any manner.

- This chapter also raises other questions and issues that can be investigated in future chapters, e.g. the status of *Alnus* in the early Mesolithic, lake hydro-dynamics and the *Corylus* rise.

Chapter Four – The South Side of No Name Hill

4.0 Introduction - Location and geology

No Name Hill (Moore's site 3; Moore 1950) is located approximately 1200 m to the north east of Star Carr and just 800 m to the south-east of the Seamer Carr sites (Figure 1.3). It appears to have been the largest island in ancient Lake Pickering, composed of mixed glacial deposits and is near some of the deepest water. The site area was discovered by John Moore during the 1940s, but was not extensively field walked until 1994 by the Vale of Pickering Research Volunteers (Lane 1998).

4.1 The Archaeological Excavations

In 1996 excavations revealed three to four areas of early Mesolithic activity concentrated in a linear area of c. 40 m along the northern-western edge of the island, where the ground falls off quite sharply into the lake. The area produced a high-density scatter of struck flints and faunal remains, at least 3 associated occupation features and a single barbed point. There was also an isolated knapping episode on the south-western side of the island at trench VP94LC and possibly another at VP86BJ and BJ86BK. Several light scatters of bone and flint occur in-between the above areas in trenches VP87BP and VP91-2KAF, which probably represent residual off-site activities, possibly connected to antler processing (Lane 1998). The location of the trenches mentioned in the text are shown in Figure 4.1. In total, 1075 lithics and 222 bones (including horse, wild cattle, red and roe deer) have been recovered from the island although they still await detailed analysis. A piece of Salicaceae wood has been identified by Rowena Gale as the result of coppicing of *Salix/Populus* trees or shrubs (Paul Lane *pers com.*). The wood was taken from an early Mesolithic context in trench NAZ and if radiocarbon dating confirms the date of the context, then this will be the earliest piece of coppiced wood to have been found anywhere in the world.

4.2 Palaeoecological Research

Three pollen profiles NM, NAQ and NAZ, taken from various locations around the island edge (Figure 4.1) were analysed for pollen, microscopic charcoal and fungi. The results from each profile are discussed separately in the next three chapters (Chapters Four to Six). The results are then correlated and a summary of the overall environmental and human impact history of the island are produced in Chapter Seven .

4.3. Sampling the South Side of No Name Hill- Profile NM.

4.3.1 Location of NM

In order to provide information about the vegetation history upon and along the southern edge of the island, profile NM was taken c. 28 m from its southern lake edge. From NM it is possible to monitor the rate of progression of the local hydrosere, any differences between the regional and local pollen rain (i.e. more detail on the status of poor pollen producing or insect pollinated plants), and lastly, information pertaining to the *Betula* decline and *Corylus* rise at the end of zone D-5 of the regional profile D. Excavations have shown that NM is located approximately 250 m to the south of the area of early Mesolithic occupation (Figure 4.1.) and presumably provides a reconstruction of pollen and charcoal deposition across a vegetation canopy.

4.3.2 Sample Excavation

Profile NM (TA 0400 8140) was retrieved during archaeological excavations in August 1994. The sediment profile was retrieved from an open trench using 0.5 m and 0.25 m monolith tins (see Figure 4.2). Depths were measured from the top of the highest monolith which was levelled to a datum of 23.6 m OD.

4.4. Lithostratigraphy of NM

The broad stratigraphy consists of glacial clays and sands overlain by organic marls with abundant plant and molluscan remains. This was then superseded by dark brown

reed peat and finally develops into a crumbly, humified ericoid and herbaceous peat. Figure 4.2 shows a colour photograph of the stratigraphy present in trench NM. The detailed lithostratigraphy was as follows:

Depth (cm)	Description
0-70	Dark brown to black crumbly, unsaturated well humified, woody detritus peat. Wood remains increase through the top 20 cm.
70-116	Dark brown semi-saturated unhumified *Phragmites* peat.
116-118	Dark brown *Phragmites* peat with dense concentration of molluscan and ostracod remains.
118-138	Olive marl with aquatic plant remains such as *Phragmites* and *Potamogeton* seeds, *Chara* oospores, molluscan and insect remains.
138-153	Pale olive marl with less dense plant remains including *Potamogeton* and reed. Contains *Chara* oospores, molluscan and insect remains.
153-159	Pale olive slightly sandy marl containing banded aquatic plant, e.g. *Potamogeton* and reed, *Chara* remains molluscs and woody fragments.
159-161	Dark grey saturated fine sand with small gravels (c. 1%) towards the base.
161-165	Light brown very smooth, sticky clay.

4.5 Pollen, Charcoal and Macrofossil Analyses

Sub-samples of 0.5 cm³ were taken for conventional pollen analysis at 1 cm intervals in the early Mesolithic and at 4 cm intervals in the later Mesolithic. In addition, selected sections of the marl sediments were sampled for molluscan and plant macrofossil remains at 0.5-1 cm intervals. All methods and procedures are outlined in Chapter Two.

4.6 Radiocarbon Dating

Five samples were submitted for small sample (AMS) radiocarbon analysis. In an attempt to establish the margin of hard water error, two samples from the same depth (155.5-157.1 cm) were submitted for AMS analysis. The results are presented in Table 4.1 (below) and on Figures 4.3-4.4:

Table 4.1   **Radiocarbon Dates from Profile NM**

Depth (in cm below datum)	Lab Code	Radiocarbon yr BP	$\delta^{13}C$ (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
12-13	Beta-86147	6160±50	-27.9	7143, 7131, 7084, 7012 (7230-6811)	Woody detrital peat
70.1-71.2	Beta-86146	8250±50	-28.5	9263, 9167, 9152 (9464-9030)	Reed peat
109-110	Beta-86145	8610±60	-28.1	9547 (9705-9493)	Reed peat
156-156.6	Beta-86144	11,400±60	-15.1	13,411 (13,793-13,059)	Wood fragments
155.5-157.1	Beta-86143	11,410±60	-11.7	13416 (13,795-13,149)	*Potamogeton* seeds

4.7 Zoning the Pollen Diagram

The pollen diagram was zoned using the computer program CONISS (Figure 4.4) and by correlation with the Regional Profile D3 (Chapter Three). In turn, the Regional Profile has been correlated with other pollen diagrams from the region and North-western Europe. The different pollen zones were dated using the top three radiocarbon dates from Table 4.1 (above) and by correlating with other palynological and palaeoclimatic research from the region, (see also Chapter Three).

4.8 The Palaeoecological Sequence

The pollen diagram (Figures 4.3-4.5) has been divided into five local pollen assemblage zones, prefixed NM. The local assemblage zones have been numbered to correspond broadly with profile D to enable easy comparison and are listed below:

Early Mesolithic c. 10,000 -9000 ^{14}C yr BP

LPAZ NM-5	161.5-125 cm	*Betula-Dryopteris filix-mas*
NM-5a	161.5-149 cm	*Betula*-Poaceae-*Filipendula* Subzone.
NM-5b	149-130 cm	*Betula-Poaceae-Dryopteris filix-mas* Subzone.
NM-5c	130-125 cm	*Betula-Corylus avellana* Subzone.

Early to Later Mesolithic c. 9000 -8600 ^{14}C yr BP

LPAZ NM-6	125-109 cm	*Betula- Corylus avellana*

Later Mesolithic c. 8600 -8350 ^{14}C yr BP

LPAZ NM-7	109-77.5 cm	*Corylus avellana-Ulmus-Thelypteris palustris*

Later Mesolithic c. 8350 -6200 ^{14}C yr BP

LPAZ NM-8   77.5-13 cm   Pteropsida (monolete) undiff-Cyperaceae-*Corylus avellana*

NM-8a	77.5-52 cm	*Corylus avellana*-Cyperaceae-*Thelypteris palustris* Subzone.
NM-8b	52-13 cm	*Corylus avellana*-Cyperaceae-Pteropsida Subzone.

Later Mesolithic > c. 6200 ^{14}C yr BP

LPAZ NM-9 13-0cm	*Corylus avellana-Alnus glutinosa-Calluna vulgaris*

The pollen and sedimentological data are described together within the framework of their local assemblage zones LPAZs in Table 4.2.

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4.9 Interpretation of the Radiocarbon Dates

The results of the radiocarbon dating (Table 4.1) can be compared to the results from Profile D and to other profiles from the local region, (e.g. Day 1996a; Cloutman 1988a, 1988b; Dark 1998).

Sample Beta-86147 provides a very young date for the *Alnus* rise at No Name Hill. This vegetation transition has previously been dated to between 7640±85 ^{14}C yr BP (Ox-4042) near Star Carr (Day 1996a), and 5990±90 ^{14}C yr BP at Flixton Island (AK 87, Innes 1994; Simmons *et al* submitted). This indicates non-synchronous establishment within the region and lends support to the hypothesis that local factors influenced its rate of establishment as suggested by Smith (1984), Brown (1988) and Chambers and Elliott (1989).

Quercus establishment also seems to be non-synchronous throughout the region. Beta-86146 dates the rational *Quercus* limit to after c. 8250±50 ^{14}C yr BP, with the empirical limit for *Quercus* appearing much earlier, in fact prior to c. 8610±60 ^{14}C yr BP. In contrast, the oak expansion at Seamer Carr does not occur until c. 6500 ^{14}C yr BP (Cloutman 1988b). The oldest securely dated level in profile NM is at the top of zone NM-6, which is dated to 8610±60 ^{14}C yr BP (Beta-86145) and which post-dates the empirical rise in *Quercus*. All the above dates are considered to be accurate.

In an attempt to establish the margin of hard water error, two samples from the same depth (155.5-157.1 cm) were submitted for AMS analysis. Sample Beta-86144 consisted of dried wood remains while sample Beta-86143 was comprised of seeds of the aquatic plant *Potamogeton*. From the low negative δ^{13}C value it can be seen that *Potamogeton* takes its carbon almost entirely from the carbonate-rich water and not the atmosphere. Unfortunately the wood remains showed a similar δ^{13}C value suggesting that the wood also originated from a plant growing within the water at the lake side. Comparison with dates for the *Betula* rise at Roos Bog, Holderness (10,120±180 ^{14}C yr, Beckett 1981), suggest that the hard water error is in the region of 1300 years, and of similar magnitude to results obtained from other calcareous lakes (Shotton 1972; Day 1996a).

4.10. Sediment Accumulation Rates

Extrapolation between the top three peat-based dates at NM suggests that the peat sequence was deposited at a rate of about 1 cm every 25 years or 0.417 cm yr^{-1}. The accumulation rate of the peat appears however to have varied considerably with values ranging from 1.11-0.29 cm yr^{-1}, depending on the particular sediment depths. Consideration of the pollen accumulation curve (Figure 4.6) suggests that although peat accumulation may have speeded up in zone NM-8a, throughout the majority of the peat sequence the sediment accumulation rate was broadly constant, and a mean accumulation time of 25 years per cm is probably fairly representative. There is no evidence to suggest that any of the radiocarbon dates are inaccurate so the very fast peat accumulation (9 yr cm^{-1}) between 109-70 cm remains enigmatic when compared with the pollen accumulation curve.

Using radiocarbon dates obtained from the lake-edge samples of Dark (1998), (see Table 4.3), it is possible to calculate the accumulation rate of the marls in profile NM:

Table 4.3   The approximate age of sediments in profile NM (see also Figure 4.7)

Approx Depth in cm in NM	^{14}C yr BP Age estimate	Approx. Cal yr BP (2σ, 95%)	Lab code /Source (Dark 1998)	Dated Horizon
124.5	8940±90	10,170 (10,239-9704)	OxA-4377	the rise in *Corylus* pollen to over 45% TLP at Star Carr
135	9385±115	10,430 (11,090-10242)	OxA-4376	arrival of *Corylus* at the lake edge at Star Carr
155	9500±70	10,715 (mid-point) (11,114-10560)	OxA- 3350	the early Holocene increase of *Dryopteris filix-mas* at Star Carr

This yields an accumulation time for the marl formation of 18.4 yr. cm^{-1}, similar to the estimate obtained for profile D (i.e. 16.2 yr. cm^{-1}). This denotes a relatively slow rate

of sediment deposition when compared with the accumulation time of 8.8 yr. cm^{-1} calculated by Day (1996a), for the marls deposited midway between Flixton Island and Star Carr. This is perhaps due to a lack of sediment input from permanent inflowing streams into the eastern side of the lake, or may reflect a higher rate of sediment re-deposition in the western end of the lake. A time depth curve for profile NM is presented in Figure 4.7.

4.11. Pollen Preservation

Analysis of the percentage of indeterminable pollen grains (Figure 4.8), can provide insights into the depositional and post-depositional processes that have affected the microfossils (Moore *et al* 1991).

4.11.1 Zones NM-5, 6 and 7 c. 161- 78cm

Unidentifiable pollen generally form less than 20-25% TLP, demonstrating that the pollen preservation conditions were very good. Unidentified grains were predominantly concealed due to the presence of metallic spheriules and resistant organic matter.

4.11.2 Zones NM-8a and 8b c. 78-26 cm

From 78 cm upwards there is a sudden change in the preservation status of the sediments. Unidentifiable pollen suddenly increases and forms between 15-30% TLP, with crumpled and deteriorated pollen each forming a significant contribution. Crumpled pollen grains indicate that the sediments have undergone compaction and deteriorated grains denote a lack of anaerobic conditions either during sediment deposition or subsequently. Concealed pollen is predominantly caused by resistant organic matter.

4.11.3 Zones NM-8b and 9   c.26-7 cm

This period signifies a slight reduction in deteriorated and concealed pollen, testifying to a possible increase in waterlogging within the sediments during and subsequent to their deposition as well as a change in the character of the organic matter.

4.11.4 Zone NM-9   c. 7-0 cm

The unidentifiable pollen curve begins to rise again, ultimately reaching 55% TLP. Deteriorated and crumpled pollen are the main contributors, presumably denoting compaction and oxidation of the sediments once more.

4.12 The Charcoal Record (Figure 4.5.)

During the early Mesolithic (prior to c. 110 cm), charcoal concentrations consist mainly of background noise from the region and surrounding catchment (i.e. <150 x 10^{-5} cm^2 cm^{-3}, see Chapter Three), with the majority of charcoal fragments derived from size classes <400 μm^2. The substantial peak in charcoal concentrations (c. 250 x10^{-5} cm^2 cm^{-3}), at the bottom of NM-5 is associated with the basal, late-glacial sands. Nichols *et al* (1997) have demonstrated that charcoal has an affinity for sand particles, therefore the charcoal peak at the very bottom of the profile is not thought to be a result of human actions.

If any fire activity had taken place on the island during the early Mesolithic it must have been restricted to the north side of the island and charcoal deposition masked by the vegetation canopy, as no charcoal peaks >150 x10^{-5} cm^2 cm^{-3} are visible. Indications of the early Mesolithic occupation at nearby Flixton Island are also non-observable. This suggests a very localised deposition of charcoal during fire events (<250-500 m), with fires confined to areas fairly close to habitation/activity sites. Sporadic occurrences of larger charcoal pieces >8800 μm^2 in the early Mesolithic sediments at NM, suggest some human occupation/fire activity in the wider landscape.

During the later Mesolithic (after 110 cm) but prior to the *Alnus* rise, catchment charcoal levels start to rise. Only concentrations in excess of c. 200 x 10^{-5} cm^2 cm^{-3} signify fire activity relatively nearby, probably within two hundred meters or less (see Chapter Three Section 3.16). At No Name Hill in the later Mesolithic (i.e. after 110 cm), fire activity is observable and was either intensive enough or near enough to register a signal on the south side of the island. The first charcoal peak (Phase 1) occurs at c. 8610±60 ^{14}C yr BP at the *Ulmus* rise and during the peak of the *Corylus* expansion. This was followed by a second larger peak (Phase 2) during the middle of

zone NM-7 at 92 cm or c. 8460 ^{14}C yr BP by extrapolation. Both fire phases include charcoal from the larger size classes >8800 μm^2 and appear to be associated with vegetation changes.

In zone NM-8a after a short period of low charcoal input, charcoal concentrations suddenly peak dramatically at a depth of 60 cm (Phase 3; c. 2500 x 10^{-5} cm^2 cm^{-3}), before declining again. Throughout the rest of zone NM-8b and into NM-9, charcoal input is sporadic but when it does accumulate, concentrations are relatively high at approximately 500 x 10^{-5} cm^2 cm^{-3} (Phase 4). Relatively small but associated changes to some types of vegetation are also observable, although these are not proportional to the size of the charcoal peaks.

4.13 Microscopic Fungi and Episodes of Burning (see Figure 4.5.)

Certain types of microscopic fungi can indicate the *in situ* conditions that prevailed during sample formation, e.g. the presence of ascospores of *Neurospora* demonstrate the occurrence of burning on the peat or at its margins (van Geel 1986). In profile NM all *in situ* evidence for burning occurs during the later Mesolithic after 110 cm, in accordance with the charcoal record. The evidence consists of abundant ascospores of *Neurospora* and identifiable charred aerenchymatous tissues resembling the pith cells of rushes and monocotyledon epidermis of reed.

In situ burning or burning nearby occurs on at least seven occasions between 108.3-46.3 cm (see Figure 4.5) and corresponds with some small-scale changes to the vegetation. Almost all of the identifiable charcoal consists of carbonised aerenchyma tissue of *Juncus* (rush) and as fossil rush pollen is never preserved, this may explain the relatively low level of impact recorded within the pollen diagram.

4.14 Synthesis and Human Impact Test 1- Conventional Interpretation of Profile NM

Commentary starts at the beginning of the Holocene.

In some respects profile NM is very similar to the regional profile D, but with slightly more input from local pollen-producing plants. The high *Betula* frequencies in profile NM reflect the regional aspect of the pollen rain which is influenced by runoff from the surrounding land. Just like the regional profile, it documents the start of *Betula* woodland formation sometime after 10,000 ^{14}C yr BP and records vegetation change until the development of alder carr c. 6000 ^{14}C yr BP. Charcoal investigations suggest that although there was Mesolithic activity on the island, the charcoal and pollen records are representative of a natural environment at least until the cessation of marl formation at the end of the early Mesolithic. This is no doubt due to the water-borne input of pollen and charcoal and the 'canopy effect' of the vegetation.

4.14.1 The early Mesolithic c. 9700-8600 ^{14}C yr BP (Figure 4.9)

Zone NM-5 is very similar to D-5 (Chapter Three). In the early Boreal, open birch woodland gradually out-competed and shaded out the willow and juniper scrub that had formed during the pre-Boreal. Willow was relegated to the wettest soils, probably forming a belt of carr at the lake edges, whilst juniper was displaced almost entirely. The insubstantial leaf canopy of the birch trees allowed plenty of light to reach the forest floor allowing an understorey of grasses and ferns, particularly *Dryopteris filix-mas* to flourish. Consequently throughout the early Mesolithic (NM-5) there was also a continuous suite of ruderal and herb taxa, e.g. *Artemisia,* Compositae, Apiaceae, *Rumex,* and Poaceae, indicative of a mosaic of communities in the woodland understorey. The open nature of the canopy is also indicated by the continual presence of woodland edge communities, e.g. *Sorbus* and *Crataegus.* The stony substrate of mixed glacial deposits would have provided a thin covering of soil and the steep lake-side slopes would increase the likelihood of soil movement providing continually disturbed areas for the germination and growth of ruderals. Constant trampling along semi-permanent trackways or at watering areas and digging over by wild boar is also a probability. Wind-throw gaps, natural tree wastage, beaver activity, ring barking of trees by animals and infrequent natural fires could also contribute to the continuation of the dynamic vegetation mosaics.

The top half of zone NM-5 marks the arrival of *Corylus avellana* in the region, an event which has been dated to c. 9400 ^{14}C yr BP at the lake edge (Day and Mellars

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1994; Dark 1998). The arrival and rise of *Corylus avellana* is fairly gradual, with frequencies remaining fairly low until the very top of the zone NM-6 where there is a population expansion. *Populus* (aspen) is notably absent from the island but this may in part be explicable by inexperience in identification during analysis of this initial profile and not necessarily due to local absence. *Pinus* pollen is very low, suggesting no local presence along the southern side of the lake edge or even upon the rest of the island. Low quantities of *Quercus* and *Ulmus* are observable from the very beginning of the Holocene, a feature which is also observable in the regional profile D.

The identification of freshwater molluscs (Figure 4.10) highlights the rapid development and establishment of lake vegetation at the beginning of the post-glacial. As one would expect from the fluvial setting, the molluscan assemblage is dominated by aquatic taxa. Table 4.2 summarises the main points arising from the study of the molluscan fauna.

By the beginning of the Holocene a thin band of reeds was already present at the very margins of the lake. The pollen data suggest the presence of floating aquatics and bulrush (*Typha latifolia*) which prefers to root in inorganic substrata (Clapham *et al* 1987). Atmospheric temperatures were slightly lower than at present and the lake water was clear with a stony substrate. Within a couple of hundred years, at around 9500 ^{14}C yr BP the lake vegetation had formed a dense band of reed beds at the lake margins which extended several meters from the shore at No Name Hill. Less than 100 years later the dense reed bed stretched nearly 30 m from the shore, with local *in situ* reeds at the sampling point. The climate was possibly even warmer than at present and the water had shallowed considerably with the development of a soft muddy substrate.

The concentration of molluscs and ostracods at the marl/reed boundary in zone NM-6 (116 cm), indicates a significant decrease in water level associated with hydrosere development and the transition from open water to reed swamp. There is no substantial pollen or stratigraphic evidence for any marked lake level fluctuations or any pronounced rise in lake levels at No Name Hill at any time during the early Mesolithic, merely the unidirectional continuation of the hydrosere.

Charcoal concentrations throughout the whole of the early Mesolithic are very low indicating a lack of burning caused by natural fires or human activities along the south side of the island at least. It is significant that the fire activity on Flixton Island (T. Schadla-Hall *pers. com.*) and the activity areas along the north side of No Name Hill during the early Mesolithic, are undetectable at this site. This implies that charcoal deposition is fairly localised and that fire activity or occurrence is limited in scale. The lack of charcoal peaks contemporary with the rational rise in *Corylus avellana* suggests that at this location, fire is not an important causal factor in its establishment.

4.14.2 The later Mesolithic > c. 8800 ^{14}C yr BP

Corylus avellana soon formed the dominant canopy vegetation upon the island, out-competing *Betula* and restricting it to the very wettest soils. *Corylus avellana* was soon joined by *Ulmus* just after c. 9000 ^{14}C yr BP , which then went on to form a local and fairly significant part of the island vegetation.

A few centimetres above the transition to reedswamp, at 112 cm and just prior to 8600 ^{14}C yr BP there is a peak in charcoal (Phase 1, 112-104 cm) associated with a small peak in *Corylus avellana* and a small decrease in *Betula,* and *Typha angustifolia* (Figures 4.12a-c). The pollen concentration curves (Figures 4.11a-b) also show a slight decline, although the curves vary considerably and are treated with caution as they appear to be reflecting changes in sediment accumulation. This episode of charcoal deposition is taken to indicate a period of human activity upon the island at a much closer range than any previous activity. Just after the main charcoal peak, microscopic charcoal of rush occurs at 108.3 cm corresponding with a peak in *Betula,* Poaceae and Cyperaceae. This can be interpreted as colonisation of open ground created by fire or the influx of pollen into areas formerly colonised by rush. The duration of this fire event is hard to estimate due to the continual deposition of background charcoal. The charcoal peak spans at least 2-3 cm or 18-27 ^{14}C yr, although the vegetational response continued for some time afterwards.

From c. 8600 ^{14}C yr BP, *Quercus* percentages were persistent but low, probably indicating sparse local presence but it was not until after 8250±50 ^{14}C yr BP (Beta-

86146) that *Quercus* becomes properly established on the island and formed a significant component of the woodland. The local abundance of both *Quercus* and *Ulmus* varied throughout the later Mesolithic and at times one or both of them may not have been locally present upon the island. As *Ulmus* and then *Quercus* began to migrate into the woodland, the stature of *Corylus avellana* changes from a canopy shrub into an understorey shrub, and its pollen concentrations drop accordingly.

In zone NM-7 *Corylus avellana* frequencies fluctuate significantly suggesting some disturbance in the woodland canopy which may also be linked to increased fire concentrations and the possible activities of later Mesolithic peoples. Evidence for woodland disturbance and open areas within in it or at its edges are shown by enhanced herb abundance and diversity, e.g. Chenopodiaceae and *Urtica,* possibly leading to localised soil deterioration and acidification as denoted by *Succisa pratensis.* *Quercus* and *Ulmus* declines could also be interpreted as greater woodland clearances by Mesolithic people, however, there is no clear or consistent link between the fire occurrence and the abundance of either *Ulmus* or *Quercus* upon the island (Figure 4.12d). Thus there is no clear evidence to suggest a human cause for their decline or eradication, although it cannot be ruled out. An alternative explanation might be that the declines in elm and oak may be the result of preferential corrosion of the pollen grains during a period of seasonal dryness.

At 92 cm (approximately 8400-8500 ^{14}C yr BP) there is another sudden peak in charcoal concentrations with the deposition of large numbers of charcoal fragments, especially particles greater than 8800 μm^2 (see Phase 2, 98-77 cm; Figure 4.5). These charcoal peaks also coincide with ascospores of *Neurospora* and changes in the frequencies of some pollen taxa. At first glance the pollen percentage diagram appears to denote a slight decrease in *Corylus* pollen associated with an increase in Poaceae pollen, but analysis of the pollen concentration diagram reveals this to be misleading (Figure 4.11a). *Corylus* concentrations actually remain constant whilst there is an increase in concentrations of herbs and grasses. This shows that although the tree canopy was unaffected there was a relative increase in the groundflora. These changes were probably the result of local fire at the lake margins as denoted by the presence of *Neurospora.* The lack of change to the tree/shrub canopy demonstrates that not all

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human disturbance in the later Mesolithic is linked with increases in the abundance of hazel. Instead, the maintenance of productive wetland and a diverse understorey may have been just as important (see also Simmons and Innes 1996a).

The rise to higher concentrations of *Pinus* pollen in zone NM-8a is dated to approximately 8250±50 ^{14}C yr BP (Beta-86146) and probably indicates a small but local presence of the tree upon the island. Any declines in *Quercus* after this time could then be caused by inter-specific competition with *Pinus* on the poorer soils where it competes best. The high sedge values in zone NM-8, along with species such as *Succisa pratensis* and Rubiaceae attest to the waterlogged and acidic nature of the depositional environment. However, the high fern values of *Thelypteris palustris,* and the occurrence of *Hydrocotyle* indicate that the environment was also seasonally dry. Seasonal drying of the sedge peat would also explain the high percentage of crumpled and corroded pollen grains throughout this and subsequent zones, as Traverse (1994) states that periodic wetting and drying of deposits is the most significant factor to affect the preservation of pollen grains. The reduction in *Ulmus* and *Quercus* pollen concentrations could also then be an artefact of the data, due to the corrosive susceptibility of the pollen grains and not due to the activities of humans.

Similarly the greater prominence of *Pinus sylvestris* at this time is probably linked to these lower lake levels and/or drier conditions or is due to the resistance of the pollen grains to decay. However, settling out of pollen grains at the lake edge is also a possibility (see Walker and Godwin 1954).

Several phases of *in situ* fire activity (Phase 3, 61-42 cm) occur during zone NM-8 which to some extent coincide with declines in *Corylus avellana* pollen and are also associated with the deposition of rush charcoal and the presence of *Neurospora.* Large fluctuations in Poaceae pollen appear to be opposite to changes in the Cyperaceae pollen curve, suggesting fairly widespread burning of the reedswamp along with some disturbance of the tree canopy (Figures 4.12e-f). The preponderance of charcoal at this time (c. 8250-6850 ^{14}C yr BP) is probably explicable by multiple periods of human occupation upon the island resulting in complex and composite changes to the

vegetation. Later Mesolithic flint scatters are fairly wide-spread over the areas of higher ground on the island. Natural fires may also have occurred upon the seasonally dry lakeside deposits as this period of fire activity corresponds to a time of drier climatic conditions and frequent natural fires over much of north-west Europe (several references cited in Tipping 1996).

A slight reduction in the percentage of corroded and crumpled grains between 26-7 cm could signify an increase in waterlogging caused by either a reduction in evaporation or an increase in precipitation (or ground water), resulting in a rise in water level within the catchment. Shortly after this postulated rise in water level, alder populations expand at this site, dated to just before 6160 ± 50 ^{14}C yr BP (Beta-86147). This expansion appears to be to the detriment of pine populations, suggesting that alder may have replaced pine at the lake edges and that prior to this, competition between the two species had prevented alder establishment. Alternatively, the pollen 'strand line' had now progressed further from the lake edge depleting pine concentrations at the sampling site.

Human disturbance of the vegetation has been cited as a possible facilitator of alder establishment (e.g. Smith 1970, 1984; Edwards 1990), although charcoal concentrations are not abnormally high prior to or at the boundary of zone NM-9. Disturbance indicators such as Chenopodiaceae and *Narthecium ossifragum* (Summerfield 1973) do increase at the top of the profile but not until after the start of the *Alnus* rise. By the top of the profile, alder carr and wet heath has started to form at the pollen site and presumably only small isolated pools of water still existed within the Vale. Human disturbance and fire activity (Phase 4, 21-0 cm) has intensified, resulting in an increase in herb diversity and the spread of *Pteridium aquilinum*.

4.15 NM Human Impact Test 2 – 95% Pollen Confidence Limits

From Section 4.14 above, there appears to be no human related vegetation disturbance along the south of No Name Hill during the early Mesolithic (i.e. before 112 cm in the profile). After 112 cm the main species thought to be associated with

human impact are:- *Betula, Corylus,* Poaceae, Cyperaceae and to some extent, *Typha angustifolia, Ulmus* and *Quercus*.

This section tests whether the fluctuations in the pollen curves are greater than the inbuilt variability in the pollen counts. Figure 4.13 shows the 0.95 confidence intervals of the pollen and spore data. The diagram has been computed and plotted using the computer program PSIMPOLL (version 4.01), (Bennett 1992, 1994, 2002).

In Figure 4.13 a high proportion of the species show pollen or spore fluctuations that exceed the 0.95 confidence intervals. This suggests that the vegetation is being subjected to factors which cause significant alterations to their pollen productivity. Human activities could be just one of these factors. From the diagram it is possible to identify samples where the pollen values are higher or lower than would be expected if the fluctuations were caused by inherent variability in the pollen counts alone. However, identifying the natural trend in the vegetation is sometimes problematic as it is sometimes unclear whether the postulated human impact has caused a peak or a decline in the pollen values. Once identified, these periods can then be compared to the charcoal curve to see if they coincide with periods of predicted human impact and changes in charcoal deposition, as summarised in Table 4.4 (below). No human impact is believed to have occurred during the early Mesolithic at location NM, so analysis starts from zone NM-6 onwards.

Table 4.4   **Periods of potential human impact in the later Mesolithic at NM, compared against charcoal deposition and 95% confidence limits**

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal pattern	Possible Human Impact (Y/N)
Corylus		110-108	Phase 1 peak	Y
		104	After Phase 1	N
		76-70	end of Phase 2	N

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Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal pattern	Possible Human Impact (Y/N)
Corylus		30-23	Small peak	?
	19		Phase 4 peak	Y
		15	Phase 4 peak	Y
Betula		116-115	Small peak	?
		108-107	Phase 1 peak	Y
	1		Peak	?
Quercus	30		small peak	?
		23	Decline	N
Ulmus		104	After Phase 1 peak	N
		23	Decline	N
Poaceae	104		After Phase 1 peak	
	92		Phase 2 peak	Y
	84-76		Phase 2 peak	?
Poaceae		23	Decline	?
	19-15		Phase 4 peak	Y
Cyperaceae	110		Phase 1 peak	?
		109	Phase 1 peak	?
	108		End of Phase 1 peak	?
	104		Decline	Y
	68		Decline	Y
		50	Decline	Y?
	46-42		end of Phase 3	Y
	30		small peak	Y

Analysis of the confidence limits of the pollen data helps to clarify the effect of human communities on the vegetation at NM. Each of the four Phases of human

occupation appears to have changed the vegetation to some extent, but the extent of these changes (especially to the canopy layer), is less marked than previously thought. The results can be summarised as follows:

Phase 1 (c. 112-104 cm; c. 150 yr) – Hazel, birch, and rush were negatively affected by human activities. Sedges may have fluctuated as a result of human occupation but there was no discernible impact on grass communities. This can be interpreted as a decrease in reduction of tree canopy and the colonisation of open ground by sedges or the influx of sedge pollen into areas formerly colonised by the trees and rushes.

Phase 2 (c. 98-77 cm; c.190 yr) - Herbs and grasses increased as a result of human activities. Canopy and understorey shrubs such as elm, oak and hazel appear to have been unaffected by any occupation. This shows that although the tree canopy was unaffected there was a relative increase in the groundflora. These changes were probably the result of local fire at the lake margins as denoted by the presence of *Neurospora*.

Phase 3 (c. 61-42 cm, c. 475 yr) – Rushes and sedges fluctuated, probably due to fairly widespread burning of the reedswamp as indicated by the presence of *Neurospora* and rush charcoal. Hazel was apparently unaffected.

Phase 4 (c. 21-0 cm; c. 525 yr) – Grass and herb diversity may have increased and hazel probably fluctuated as a result of this phase of fire activity.

In addition there may have been a further two episodes of human related alterations to the vegetation, at 116-115 cm (zone NM-6) and 30-23 cm (zone NM-8b). Both of these episodes appear to result in alterations to the vegetation but in both circumstances, charcoal concentrations are only just at or below the background levels defined in Section 3.15. The possible modifications to the vegetation are:
116-115 cm – reduction in birch.
30-23 cm – peaks in oak, grass and sedges.

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4.16 Human Impact Test 3 – Background Variations and 95% Confidence Limits

The three-stage model to test human impact that was proposed in Chapter Three, is only applicable to the early Mesolithic, as this is the period when human alteration of the vegetation is currently undetectable at a regional level. Due to the absence of prolonged charcoal peaks, human impact cannot be detected with any certainty. Nonetheless, profile NM provides the opportunity to test the model, to see whether it agrees with the conclusion that there was no human impact in the early Mesolithic at NM. (Due to the complexity of the test, and its time consuming nature, only *Betula* will be tested).

Figure 4.14 plots the percentage of *Betula* pollen at NM during the early Mesolithic. The natural trend in birch abundance is illustrated by a regression line drawn through the data. This is the mean trend in the vegetation if the tree canopy were to be unaffected by human activities. The inherent variability in the pollen data (IV, ±4.2%) is plotted alongside the trendline, and represents the variation that can be expected as a result of the pollen percentage counts. Finally, the combined value of background fluctuations (BV) and inherent variations (IV) in the data (E), is also plotted alongside. (For calculations see Table 4.5 below).

Table 4.5 Calculating the Total Variations (E) in *Betula* pollen at NM

Profile	Species	NM % IV	D3 % BV	NM % Range	D3 % Range	BV Scaling factor	NM % BV	E %= $\sqrt{(IV^2+BV^2)}$
Zone NM-5	Betula	4.2	9	78-40	78-37	1.00	9	9.93

Figure 4.14 illustrates that the variations in *Betula* pollen do not exceed the expected variations (IV and BV combined), due to pollen count variations, climate, soil, competitive and seasonal variations in pollen output. This provides support for the hypothesis that there is no human impact at NM in the early Mesolithic.

4.17 Human Impact at NM - Conclusions

There was little or no human occupation (at least no long burning fires), and no discernible human alterations to the vegetation along the south side of No Name Hill during the early Mesolithic.

During the later Mesolithic, there appears to have been approximately four periods of fairly long term (or intermittent) human occupation upon the island. Each phase of activity lasted between 150-525 years in total, but probably consisted of numerous periods of short-term occupation.

All phases of occupation appear to have affected the vegetation in some way, although it has not been possible to allow for any background variations in pollen production, caused by natural factors. Canopy and understorey shrubs were sometimes affected but the main alterations appear to have been to the groundflora and reedswamp. On the whole, sedges, grasses and ruderals fluctuated or increased during or after human activities, whilst rushes were the apparent victim of the majority of the fires. The presence of *Neurospora* fungi and rush charcoal testifies to the burning of the reedswamp, although rush (*Juncus*) pollen is not preserved in a fossilised form so the impact on the rush populations is uncertain. It is possible that populations of reeds were also burnt, and that this led to an increase in their pollen production in the following years (see Thompson and Shay 1985, 1989), however because reed charcoal is more fragile than rush charcoal, it may not have been so readily preserved within the sediments (see Day 1991).

4.18 Comparison of NM with the natural vegetation, Profile D

The work of Walker and Godwin (1954), Day (1996a) and Chapter Three (this volume), enable comparisons to be made between profile NM and the regional/natural vegetation. Unfortunately the data of Walker and Godwin (1954) are fairly limited their use as the data are displayed as percentage total tree pollen and not in terms of percentage TLP.

According to sequence D (Chapter Three), *Corylus avellana* pollen increases sharply to over 50% TLP at the end of zone D-5c. However, profile NM suggests that the rise in *Corylus avellana* is more gradual. The differences can be explained by a slow down in accumulation and compaction of sediments or a hiatus at c. 465.5 cm in sequence D, caused either by a sampling break (two cores overlap at this point) or a cessation in marl deposition. The hiatus appears to be equivalent to approximately the whole of zone NM-5c, (or c. 90 yr by extrapolation). Contrasting profile NM with profile D also indicates that in the regional picture *Quercus* and *Ulmus* pollen levels are elevated, *Pinus* levels are lower in the later Mesolithic and wet heath is absent. In Day's (1996a) profile, oak appears much later than at NM, elm levels are higher, pine plays a less significant role in the vegetation during the later Mesolithic, and the arrival of alder is much earlier.

The delay in oak immigration is explained by a hiatus in Day's (1996a) profile, something which appears to have been confirmed by analysis of Profile D (Chapter Three) and the work of Walker and Godwin (1954:43). The lower levels for elm and oak at NM, the higher levels of pine, differing rates of alder establishment and occurrence of wet heath are all explained in Section 4.20 which compares the results at NM to the Vale as a whole.

4.19 Comparisons of NM with Star Carr

The results from NM can be compared with all the previous work from Star Carr undertaken by Walker and Godwin (1954), Cloutman and Smith (1988), Day (1993), Day and Mellars (1994), Mellars and Dark (1998). However such comparisons are limited due to the lack of human impact at NM and the truncated pollen profiles from the Star Carr sites.

The *Salix* frequencies in monolith A3 and monolith B (Cloutman and Smith 1988), are comparable with the frequencies at NM, i.e.<20% TLP. This is a reflection of the distance of the profiles from dry land and indicates that despite the low values for *Salix*, a band of willow carr may well have been present around the southern lake edge of No Name Hill. In hindsight the results of Cloutman and Smith (1988) also

demonstrate that at 30 m from the lake edge, in monolith VP85B, the indications of human disturbance identified by Mellars and Dark (1998) are still observable, although less pronounced, e.g. the decline in reeds, male fern, fluctuations in birch and the peaks in nettles, ruderals and aspen. Bearing this in mind, the lack of charcoal and human disturbance at NM must be a real reflection of the lack of occupation along the southern lake margins during the early Mesolithic. The pollen curves from NM are therefore taken to be a reflection of the natural vegetation until the cessation of marl deposition.

Comparison of the male fern and birch curves from NM (Section 4.15) reveals that there are fairly extensive natural fluctuations in the pollen output of both species. This includes a bimodal pattern in the *Dryopteris filix-mas* curve showing that a natural decline in *Dryopteris filix-mas* spores (percentage and concentration) occurred at approximately the same time as occupation at Star Carr. It does not take much imagination to see that the broad outline at NM is comparable with the male fern curve from Star Carr (Day 1993), especially given the different sample resolutions, see Figure 4.15. It is proposed that some (not all) of the changes to the vegetation that were attributed to human action (Day 1993; Day and Mellars 1994; Dark 1998) were in fact due to natural (perhaps climatic?) changes in pollen/spore output.

4.20 Comparisons of NM with the rest of the Vale

4.20.1 Early Mesolithic

Betula levels are higher at NM than at other parts of the lake edges, as the pollen input is a function of the distance from land and proportion of local input from carr/reedswamp pollen. The *Betula* rise, which is likely to have been fairly synchronous in the lake area, has been dated to 10,275±175 ^{14}C yr BP at Flixton AK87, approximately 500 m to the south-west (Figure 1.3).

4.20.2 Later Mesolithic

During the later Mesolithic, No Name Hill provides an insight into some of the landscape mosaics that may have occurred and which are not identified in the regional pollen rain. Evidence from NM alludes to the local presence of small areas

of pine in a forested landscape. Innes' (1994) profile AK87, suggests local pine canopy dominance in some areas and *Pinus* pollen is recorded at significant levels (>20% TLP) in later Mesolithic deposits at a number of other , e.g. Seamer Carr (Cloutman 1988b). *Pinus* therefore, appears to be important locally but not regionally.

At NM, the pollen values for *Ulmus* and *Quercus* are much lower than indicated by the regional pollen rain but as the later Mesolithic sediments at NM no longer reflect the regional environment, some differences between the local (island) vegetation and the regional vegetation are to be expected. The soil on top of No Name Hill would probably have given rise to shallow, sandy, well drained soils poor in nutrients and as such delayed the expansion of alder or reduced the competitiveness of *Quercus* (Turner and Hodgson 1981:187). The low nutrient status of the soil on the island and low altitude would also mean that *Ulmus* is liable to competition from *Pinus* (Turner and Hodgson 1979; 1981). Higher proportions of heavy clays along the Vale sides, would provide more suitable habitats for *Quercus* and account for its elevated regional pollen rain.

The period of wet heath formation that occurred at 6100 ^{14}C yr BP at NM is not reflected in any other profiles around the lake including the two regional profiles. Day's (1996a) profile ends too early and although profile D documents some *Calluna* heath development within the region, the pollen signal is not large enough to indicate widespread occurrence. The absence of wet heath and pine populations from the regional diagrams can be explicable by the presence of localised patchy populations around the lake. In a lake of this size vegetation patchiness is often hard to detect because of the source area of the regional pollen. As the patches in the vegetation are small in comparison to the catchment area, the vegetation often appears homogenous when in reality it is not (Sugita 1994:881). However, pollen profiles from the lake edges are near enough to be influenced by local and extra-local pollen inputs, which is why they often differ from the regional pollen diagrams. This also provides a validation for the research project, showing that it is realistic to look for localised human impact in lake edge sediments from a lake of this size.

In Day's (1996a) profile there is an abrupt increase in charcoal concentrations after 7600 ^{14}C yr BP which is sustained until the top of the profile at 6500 ^{14}C yr BP, a similar but undated pattern also occurs in Profile D. In contrast, NM charcoal concentrations (and Charcoal:pollen ratio) gradually increase from c. 9000 ^{14}C yr peaking at c. 7900 ^{14}C yr BP but this is not sustained. Such observations provide further confirmation that charcoal deposition throughout the lake edges is very localised, with the lake centre/regional profiles obtaining charcoal from both the aerial catchment and re-deposited/sediment focused charcoal from the lake sides.

4.21 Wider Issues

The reconstruction of water levels throughout the lake unit is problematic due to the differing locations of the pollen profiles in relation to the lake-shore. This results in great variations in local vegetation with contrasting pollen source areas, differing rates of hydrosere development and depositional environments. The level of information provided by each author also varies restricting some types of analysis, e.g. pollen preservation. As a consequence correlation between profiles is often problematic and sometimes results in conflicting conclusions. Nevertheless, some broad trends have been identified.

To begin with Walker and Godwin (1954:69) proposed that during Zone V there was a rise in the lake level as the outlet at the western end of the lake silted up. Cloutman (1988a) also proposed higher lake levels early in the Holocene, by c. 9500-9000 ^{14}C yr BP. However, at NM there are no apparent unidirectional changes in the lake levels during the early Mesolithic although this is probably partly a function of the water depth at the sampling point.

During the later Mesolithic, towards the middle of Godwin's zone VI at approximately 8250 ^{14}C yr BP (NM-8a) there appears to have been a change in the hydrological zone at NM resulting in a decrease in lake level or change in the precipitation/evaporation ratio. This resulted in the formation of seasonally dry sedge carr with high proportions of ferns and possibly local stands of pine. Dry conditions at c. 8000 ^{14}C yr BP have also been inferred from hiatuses in deposits in eastern

England, The Lake District and Eastern Ireland (cited in Tallantire 1992). At Hockham Mere, East Anglia, the most severe conditions occurred between 7800-7500 ^{14}C yr BP while Rybnîcek and Rybnîckova (1987), cite seasonal droughts elsewhere in Europe over the same periods. Further analysis around the lake is required before these periods can be interpreted as a time of regionally drier climatic conditions.

Sometime later (c. 6600 ^{14}C yr BP) there appears to have been a rise in water level at NM as the pollen preservation curve indicates a drop in pollen deterioration between 26-7cm (top NM-8b). This coincides with the first appearance of *Alnus* in the profile. There is also evidence for a rise in lake level at Seamer Carr (Cloutman 1988b) around this time as at CVIII (c. 24.1 m OD) when carr was replaced by reed swamp. This event has been dated to around 6500 ^{14}C yr BP (Cloutman 1988b), a date which is not inconsistent with the evidence from NM. Walker and Godwin (1954:69) also suggest a slowly rising water table after c. 7000 ^{14}C yr BP caused by rising sea level and blockage of the lake overflow.

The *Alnus* rise at No Name Hill is dated to 6160±50 ^{14}C yr BP and is considerably later than a date of 7640±85 ^{14}C yr BP obtained from a core just 800m to the south-east of No Name Hill (Day 1996a). In fact the arrival of alder at NM is approximately 1500 years later than other established dates in northern England (Huntley and Birks 1983; Smith 1984). Some delay may be linked to the lag in northwards migration around the lake edge and to the belated arrival upon the island, but even conservative estimates for migration rates may not explain this anomaly. This topic will be investigated in more detail in Chapter Eleven.

4.22 Chapter Four – Summary
The main points to arise from this chapter are:
- Analysis of the remains of freshwater molluscs shows that there was a rapid development of emergent and aquatic vegetation at the beginning of the post-glacial.

- There is no evidence for local fires at NM during the early Mesolithic. If fire activity did occur on the island during this time period it must have been restricted to the north side of the island, with charcoal deposition masked by the vegetation canopy.

- Consequently, in the early Mesolithic there are no observable changes to the vegetation, caused by human activities.

- Early Mesolithic fire activity at Flixton Island is not observable at NM, suggesting a very localised deposition of charcoal during fire events (250-500 m), with fires confined to areas fairly near habitation/occupation sites.

- During the later Mesolithic fires are either intensive enough or near enough, to register a charcoal signal at NM. There are approximately four fire phases on the island during this time.

- The reedswamp was burnt on at least five occasions, resulting in the deposition of microscopic charred remains of rush and reed, and the presence of *Neurospora* fungi.

- Canopy species such as hazel and birch were sometimes affected by human activities, but the main alterations appear to have been to the groundflora and reedswamp, e.g. grasses, sedges, rushes and herbs.

- Rush was apparently the main victim of the fires, indicated from the presence of microscopic charcoal particles, although this may be purely the result of taphonomic issues.

- Oak and alder were relatively late colonisers of the island, becoming established at c. 8200 and 6200 ^{14}C yr BP respectively. Poplar seems to have been totally absent.

- Around the same time that alder was colonising the island edges, wet heath was also forming around No Name Hill.

- There appear to have been water level fluctuations at No Name Hill, during the later Mesolithic, but these will be investigated in more detail in Chapter Eleven.

Chapter 5 - The North Side of No Name Hill

5.0 Profile NAQ

Profile NAQ (TA 0400 8150) provides information about the vegetation history and possible human impact on the north side of No Name Hill during the early Mesolithic, complementing the information obtained from the south side of the island at NM (Chapter Four). The location of the profile from the northern edge of the island was determined following the results of 'in the field' pollen preservation tests as described in Chapter Two. The tests revealed that pollen preservation at the lake edge was poor and that in order to obtain statistically significant pollen counts for the whole of the early Mesolithic, the profile needed to be taken several meters from the early Mesolithic shoreline. Profile NAQ was therefore taken from the north side of the island approximately 28 m from the early Mesolithic lake edge, where there were dense concentrations of early Mesolithic finds (Figure 5.1).

5.1 Sampling

The sediment profile was retrieved from an open 2x2 m trench and sampled using three 0.5 m overlapping monoliths. The top of each tin was levelled, before being cut from the cleaned north facing section of the trench, wrapped in polythene to prevent contamination and then stored at 4°C prior to analysis. The top 1.5 m of peat was very crumbly and oxidised, so it has not been included in the analyses. All measurements were taken from a datum of 24.28 m OD.

5.2 Lithostratigraphy

The profile consists of basal grey sands overlain by deep water marls which are covered by a layer of sticky grey clay. The clay is then superseded by organic lake muds, which are finally overlain by reed peats. The detailed lithostratigraphy was as follows (see Figure 5.2):

Depth (in cm)	Description
144-156	Very dark brown crumbly reed peat.
156-172	Very dark brown organic mud with extensive vegetative remains.
172-177	Dark brown organic mud with vegetative, reed and molluscan remains.
177-181	Brown organic mud with marl and some molluscan remains.
181-184.5	Dark brown organic mud with extensive reed fibres and molluscan remains.
184.5-189	Grey, sticky clay with abundant fragments of black slate/manganese.
189-204	Light olive marl with molluscan remains
204-208	Grey organic sand with small angular gravels.

5.3 Pollen and Microscopic Charcoal Analysis

Sub-samples for pollen and microscopic charcoal analysis were taken every 1-4 cm. After consideration of the preliminary results, finer resolution sampling was also undertaken at contiguous 2.5 mm intervals from a 6 cm section of the profile between 179-185 cm. Only the bottom 0.65 m of the sediment profile was analysed, due to the poor pollen preservation in the upper sediments.

5.4 The Palaeoecological Sequence

5.4.1 Zonation

The percentage pollen diagram (Figures 5.2-5.4) has been divided into three local pollen assemblage zones (prefixed NAQ) using the zonation program CONISS (Grimm 1986). The local assemblage pollen zones have been compared and correlated with Profile D (Chapter Three) and numbered accordingly, to broadly correspond with profile D, for easy correlation. Profile D in turn, has already been correlated with other profiles from the region and North-western Europe (see Chapter Three).

5.4.2 NAQ LPAZs

The resulting pollen zones have been identified as:

Early Holocene (early Mesolithic) c. 9700-9000 ^{14}C yr BP

<u>LPAZ NAQ-5</u> <u>209 cm-61.5 cm</u> <u>*Betula*-Poaceae-*Dryopteris filix-mas*</u>

NAQ-5a   209 cm-189 cm   *Betula*-Poaceae-*Filipendula*

NAQ-5b   189 cm-171.5 cm   *Betula*-Poaceae-*Dryopteris filix-mas*

NAQ-5c   171.5 cm-161.5 cm   *Betula*-Poaceae-Cyperaceae

Early to Later Mesolithic > c. 9000 ^{14}C yr BP

<u>LPAZ NAQ-6</u> <u>161.5 cm-154 cm</u>   <u>*Corylus avellana*-Cyperaceae-*Typha*</u>

<u>*angustifolia*</u>

Later Mesolithic > c. 8250 ^{14}C yr BP

<u>LPAZ NAQ-7 154 cm-136 cm</u>   <u>*Corylus avellana* – Cyperaceae - Pteropsida</u>

<u>(monolete) undiff.</u>

The LPAZs and sedimentological data are described in Table 5.1.

5.5 Radiocarbon Dates

Two samples were submitted for radiometric radiocarbon analysis. The results are presented in Table 5.2. below:

<u>**Table 5.2**</u>   <u>**Radiocarbon Dates from NAQ**</u>

Depth (in cm below datum)	Lab Code	Radiocarbon yr BP	δ^{13}C (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
154-6	Beta-104483	9810±160	-29.7	11,199	Crumbly reed peat
164-6	Beta-104482	9570±130	-28.1	11,062; 11,015; 11,012; 10,943; 10,842; 10,829; 10,786;	Crumbly reed peat

Both samples were given extended counting time due to their small sample size. The δ^{13}C values for both samples are acceptable for peat and therefore no hardwater error is likely. Sample Beta-104482 was taken to provide an approximate date for

the *Corylus avellana* rise on the island (i.e. 9570±130 ^{14}C yr BP). Radiocarbon determinations from the lake edge at Star Carr date the *Corylus* rise there to 9385±115 ^{14}C yr BP (Day and Mellars 1994, Mellars and Dark 1998). The date of 9570±130 ^{14}C yr BP for Beta-104482 is therefore tentatively taken to be correct, bearing in mind the large standard error for the sample. The radiocarbon plateau at 9600 ^{14}C yr BP, does however mean that the sample has seven possible calendar ages (Table 5.2, above).

The second sample, Beta-104483 was taken to date the beginning of the charcoal rise at 154 cm, but has provided an unacceptably old date given its supposedly younger and stratigraphically higher position in comparison to Beta-104482. Housley (1998:27) observes that: *"There is no readily identifiable reason why this determination should be incorrect both in terms of the pollen assemblage it is associated with, and its position in the profile.......All in all Beta-104483 remains something of an enigma."* As a consequence only sample Beta-104482 will be used to date profile NAQ in the subsequent analyses.

5.6 Sediment Accumulation Rates

Using the radiocarbon dates listed in Table 5.3. (below), it is possible to calculate the accumulation rate of the sediments in profile NAQ, up until the end of the early Mesolithic. The resultant accumulation time is 16.7 yr cm^{-1} or a rate of 0.06 cm yr^{-1}. This appears to be fairly typical of the early Mesolithic sediments analysed so far in this study i.e. profiles D and NM. Assuming the total pollen concentration diagram (Figure 5.6a), is a reliable indicator of sediment accumulation, then profile NAQ follows a very similar pattern to NM, in terms of total concentration, and by inference accumulation time. This is born out by the similar accumulation time of 18.4 yr cm^{-1} at NM (Chapter Four). The total pollen concentration curve is actually reflecting the increasing productivity of the environment during the first centuries of the post-glacial. This is then followed by a huge increase in productivity (or reduction in accumulation) at c. 9500 ^{14}C yr BP, around the time of the *Dryopteris filix-mas* rise.

Table 5.3 The approximate age of sediments in NAQ (see also Figure 5.6b)

Approx. Depth in cm in NAQ	14 C yr BP age estimate	Approx. Cal yr BP	Lab Code/ Source	Dated Horizon
161.5	8940±90	10,170	OxA-4377 Dark (1998)	The *Corylus* expansion at Star Carr
165	9570±130	c. 10,924 (midpoint)	Beta-104482	The *Corylus* rise at NAQ
172	9385±115	10,430	OxA-4376 Dark (1998) Dark (2000)	The empirical *Corylus* rise at Star Carr
195	9500±70	10,715 (midpoint)	OxA-3350 Dark (1998)- Dark (2000)	The early Holocene rise in *Dryopteris filix-mas* at Star Carr
207	c. 9700	c. 11,165	Day (1996a) Dark (2000)	Start of Pre-Boreal

The period of fine resolution sampling during zone NAQ-5b was undertaken to investigate the vegetation changes on the island over time spans of just a few years. A sediment accumulation time of 16.7 yr cm^{-1} provides a sample resolution of 4.175 yr per 2.5 mm sample and is broadly analogous to the 4.05 yr sample resolution of the lake centre deposits in Chapter Three. This should enable comparisons between the natural variations in the environment and any human induced changes to the vegetation upon the island. However, the total pollen concentration curve at NAQ (Figure 5.6a), reveals that the accumulation rates were very variable even over short time-spans. This could be a reflection of human soil disturbance although there is little correlation between the charcoal and pollen concentrations curves.

Due to the scarcity of dates in profile NAQ and the lack of correlation with other profiles from the Vale, (mainly caused by low *Ulmus* and *Quercus* values), calculating the rate of peat formation during the later Mesolithic is problematic. Careful comparison of the pollen curves from NAQ and NM from the south of No Name Hill, suggest that the top of NAQ correlates with the depth of 70 cm in zone NM-8, dated to 8250±50 ^{14}C yr BP. This conclusion is based on the total

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concentration curves and the pollen concentration curves of *Pinus* and *Corylus*. As NM is approximately the same distance from the lake edge it is logical to assume that similar vegetation changes are broadly contemporaneous. These assumptions provide a highly credible peat accumulation time of 27.1 yr cm^{-1}. A time-depth curve for NAQ is presented in Figure 5.6b.

5.7 Pollen Preservation (Figure 5.7)

Analysis of the levels of pollen preservation (Figure 5.7) can provide insights into the depositional and post-depositional processes that have affected the microfossils (Moore *et al* 1991).

5.7.1 Zone NAQ-5a   209 cm-198.5 cm

Total unidentifiable pollen levels are generally less than 20% TLP and consist of almost equal inputs of corroded, crumpled and concealed grains. The first two types are probably caused by secondary inputs of eroded or reworked pollen during this initial stage of the post-glacial, also attested to by the presence of Pre-Quaternary spores. The remaining unidentifiable grains are primarily caused by concealment behind metallic sphericals and grains of quartz.

5.7.2 Zones NAQ-5a-5d   198.5 cm-160.5 cm

Pollen preservation is almost perfect during these levels. Total unidentifiable pollen grains often account for <10% TLP, although on some levels they do reach nearly 15% TLP. The majority of these grains are caused by concealment behind metallic sphericals and not as a result of physical processes.

5.7.3 Zones NAQ-6 -7   160.5 cm-136 cm

Pollen preservation levels begin to deteriorate gradually between 160 cm and 155 cm before stabilising. Corroded grains are the primary contributors followed by equal inputs of crumpled and concealed grains. Post-depositional oxidation and compaction processes are likely to have caused these changes in preservation. Concealed grains are primarily obscured by pieces of resistant organic matter, which are often found in lowland peats (Richardson and Hall 1994).

5.8. The Charcoal Record (Figures 5.4 and 5.5)

At the bottom of the profile (207 cm), charcoal concentrations start off at c. 200 x 10^{-5} cm^2 cm^{-3} before immediately declining to background catchment levels (i.e. ≤ c. 150 x10^{-5} cm^2 cm^{-3}). These enhanced concentrations are probably caused by an affinity with sand particles (Nichols *et al* 1997) and not caused by human-related fire activity upon the island. However, just after the beginning of the *Dryopteris filix-mas* curve, charcoal concentrations suddenly increase substantially to c. 300-600 x10^{-5} cm^2 cm^{-3} at a depth of 185 cm. These levels are 2-4 times as high as charcoal concentrations at the lake centre during this period.

The irregular nature of the charcoal (and pollen curves) reinforces the hypothesis that there was no mixing of the lake sediments and supports the application of fine resolution analyses. The prolonged and erratic nature of the charcoal deposition also identifies this as a period of human fire activity in the surrounding landscape. These high charcoal concentrations (> 300 x10^{-5} cm^2 cm^{-3}) are maintained over a stratigraphic depth of 6.5 cm (184.5-178 cm), which is equivalent to approximately 110 years of sediment deposition (from Section 5.6). The erratic nature of the curve suggests that the importance or intensity of the fires varied through time, perhaps even including periods when fire was not used or when the settlement area was abandoned. This is best illustrated by looking at the number and size composition of the charcoal fragments (particularly macro pieces) which are shown in Figures 5.4 and 5.5. Consequently what initially appears to have been one phase of activity spanning c. 6.5 cm between 178-184.5 cm, is actually composed of multiple sub-phases, of which there are perhaps four.

Charcoal concentrations in the succeeding periods (177-161 cm) are much lower, generally less than 300 x10^{-5} cm^2 cm^{-3}, although often still higher than background levels. The jagged edged profile of the charcoal diagram suggests several further periods of fire activity in the surrounding landscape, which were either less intense in nature or further away than during the preceding phase of human activity, perhaps within a couple of hundred meters. By looking at the number of macro particles and size classifications of the charcoal fragments, this additional period of burning

(between 177-161 cm) appears to have been composed of an additional three to five sub-phases of activity.

Finally, at the very end of the early Mesolithic and during the beginning of the later Mesolithic i.e. after 161 cm, charcoal concentrations become elevated once again. Two further phases of fire activity occur, each producing peaks in the charcoal concentration diagram of c. 600×10^{-5} cm^2 cm^{-3}. This is equivalent to three times the background charcoal levels for zone D-6 in the regional profile later Mesolithic (Chapter Three). However, compared with the preceding fire phases at NAQ, fewer charcoal fragments appear to have been produced. Those that were present belong to the larger size classes, which perhaps denotes a period of more localised fire activity.

All phases of fire activity appear to correspond to some type of vegetation fluctuation. The exact response of the vegetation to each phase of fire activity will be detailed in Section 5.11. The deposition of different charcoal particle size classes also demonstrates fairly clearly, the findings of Pitkänen *et al* (1999), *i.e. "an increase in proportion of largest particles and a decrease in particle size c.<10 µm in diameter suggest local burning. The result may be due to fires of a low intensity in the area"*. To enable easy reference to be made to each different period of fire/human activity, the charcoal record has been split into 'Phases' and 'sub-Phases' as shown in Figures 5.4, 5.5 and Table 5.4 below.

Table 5.4   Proposed 'Phases' and 'sub-Phases' of Fire/Human Activity

Stratigraphic Depth (in cm)	Phase/sub-Phase of Fire/human Activity
209-185	Pre- Phase 1.
185-177	Phase 1-a, b, c, and d.
177-160	Phase 2-a, b, c, d and e.
160-148	Phase 3
148-136	Phase 4

Analysis of the Charcoal:pollen ratio diagram demonstrates that the difference between Phase 1 and 2 was unlikely to have been as marked as the charcoal concentrations suggest. The two phases appear to be nearly comparable in terms of fire intensity and/or location to the sampling site, with Phases 3 and 4 much more intense and or nearer. The latter can be explained by the relative location of the activity to the sampling point over time, as the edge of dry land progressed outwards as a result of the local lake hydrosere. The difference between the charcoal concentration curve and the charcoal:pollen ratio is the result of differing sediment accumulation rates either diluting or enhancing the charcoal signal in the samples. Another point to emerge is that prior to Phase 1 and very early in the Holocene, there may have been at least another two phases of fire activity within the localised catchment.

5.9 Charcoal Identified to Species (Figures 5.4 and 5.5)

The occurrence of characteristic cell types in the microscopic fraction of the charcoal can also provide useful clues as to the possible origins of the charcoal (Day 1991). In profile NAQ, two characteristic types of microscopic charcoal were identified. Microscopic charred aerenchymatous tissues resembling the pith cells of rushes and monocotyledon epidermis of reed have been identified from levels at 152 cm, 183.37 cm and 183.63 cm respectively, which reveals the type of vegetation that was combusted at these times. The presence and absence of these charcoal fragments are illustrated in Figures 5.4 and 5.5.

5.10 Microscopic Fungi (Figures 5.4 and 5.5)

The presence of certain types of microscopic fungi within a pollen sample can indicate the type of *in situ* conditions that prevailed during sample formation. Identification of fungal spores was undertaken using the photographs provided by van Geel 1986, Boyd 1986, and van Geel *et al* 1989 (see also Chapter Two).

In profile NAQ nine types of fungal spore were identified. The occurrence of ascospores of *Neurospora* at 182.63 cm and at 148 cm at NAQ, indicates the

presence of fire on the mire or at its margins (van Geel 1986). The presence and absence of these spores are also illustrated in Figures 5.4 and 5.5. *Zygnema* type spores (Type 314), also appear to indicate increasing mineralisation in the catchment runoff and so their presence at 193 cm, 181.63 cm and 176 cm may indicate soil disturbance on the island, perhaps also linked to the occurrence of fire.

The majority of the identifiable spores belong to *Geoglossum* algae, which tend to occur amongst *Carex* sedge stands in hummock and pool vegetation formations (van Geel *et al* 1989). These conditions exist from 196 cm until 136 cm, although towards the top of the profile after 161 cm, relatively dry terrestrial conditions prevailed at the site, attested to by the presence of spores of Type 10, 200 and 201. The presence of spores of Type 173, 173A, 225 and 314 in the lower section of the profile, indicates an alkaline lake environment with pools of water and hummocks colonised by *Carex* communities (van Geel *et al* 1989).

5.11 Synthesis and Human Impact Test 1 - Conventional Interpretation of Profile NAQ

Profile NAQ documents the early post-glacial vegetation development at the northern lake edge of No Name Hill from the early Mesolithic through to the beginning of the later Mesolithic c. 8250±50 ^{14}C yr BP, a period of approximately 1500 years. The pollen concentration curves for most taxa frequently rise and fall in unison and it is clear that they are responding to changes in sediment accumulation as well as changes in pollen production, consequently the concentration data are used with caution.

Phases of increased charcoal deposition are analysed in relation to human impact on the vegetation, using conventional methods of analysis (i.e. Test 1 in a 3-stage test for human impact [HI]).

5.11.1 The earliest Mesolithic c. 9700 to> c. 9500±70 ^{14}C yr BP

Sedimentation begins in open water sometime after 10,000 ^{14}C yr BP, probably at c. 9700 ^{14}C yr BP (c. 11,165 cal BP) at the end of the pre-Boreal and just prior to the

start of the *Dryopteris filix-mas* (male fern) expansion. At the start of zone NAQ-5, open birch woodland with willow and scattered juniper had already become established. Populus pollen is almost totally absent within the profile suggesting aspen may not have been a significant part of the island vegetation even discounting its poor pollen dispersal. Grass pollen is particularly high, possibly derived from *Phragmites* growing *in situ* within the nutrient-rich water, as almost all the pollen grains are less than 26 µm in diameter. (Poaceae pollen grains <26 µm in diameter are consistent with the grains of the reed *Phragmites australis* (Faegri *et al* 1989)). The pollen grains also occur in clumps which indicates their local origin (GreatRex 1983, Janssen 1986).

The arrival and peak of *Dryopteris filix-mas,* which is a characteristic feature of the early Mesolithic, is believed to have been synchronous around the lake edge. The spore category *Dryopteris filix-mas* type includes several species of male fern and other ferns of woodland and rocky open places (Moore *et al* 1991). Consideration of the soil and habitats likely to have been available during the early Mesolithic suggests that male fern is likely to have been the main contributor to the spore count as it is a woodland floor dominant and coloniser of well drained substrates (Grime *et al* 1991). The understorey of the early Mesolithic woodland is likely to have been predominantly composed of stands of this plant, which probably extended out beyond the woodland edge. Grasses and meadowsweet *(Filipendula)* would also have contributed to the ground flora, the latter on the wetter soils nearer the lake edges. Throughout the early Mesolithic (zone NAQ-5) the woodland shrub and ground flora was diverse and soils were still unstable as indicated by the presence of ruderals, e.g. *Artemisia.* Topographic surveys of the Mesolithic island surface show that the island edges were notably steep sided and thus soil instability at the lake edges was probably widespread.

5.11.1.1 Pre-Phase 1

Prior to charcoal Phase 1 (> c. 9500±70 ^{14}C yr BP, > c. 10,715 cal yr BP), there are several pronounced fluctuations in the pollen frequencies for some of the canopy and groundflora species (Figures 5.2-5.4). Oscillations in the pollen frequencies of *Betula, Filipendula* and Pteropsida (monolete) undiff. pollen tend to be the opposite

to changes in the *Salix* and Poaceae pollen curves. The pollen concentration curves (Figure 5.8) for most species rise and fall together, reflecting changes in accumulation rates at the lake edges, consequently little supporting evidence can be deduced from the pollen concentration data. *Betula* values were less affected by the fluctuations compared to most of the other species, so it can be deduced that the extent of *Betula* woodland actually did change. The fluctuating pollen groups appear to be reflecting the tree and understorey responses of two separate vegetation communities. Such a response suggests direct competition between the two communities, unfortunately the exact reason for these changes is uncertain. However there are several possible scenarios which could be used to explain these pollen fluctuations, all of which need to be considered.

The pre-Phase 1 pollen fluctuations could have been caused by poor *Betula* seedling establishment within mature stands of birch, which caused transient periods of forest patchiness (Grime *et al* 1991). The short-lived openings in the canopy would have then been exploited by *Salix* which was able to expand into these areas for a limited period in the absence of any other competitors. Alternatively, heavy grazing by wild animals at selected lake edge spots could have prohibited *Betula* seedling establishment and eradicated *Filipendula,* whilst favouring perennial grasses and the representation of lake edge trees. Another option is that animal wallowing or felling of trees by beavers may have created pools and raised the water table in small areas killing stands of *Betula* but favouring the establishment of *Salix* and wetland grasses.

Another possibility is human modification of the environment. *Betula* and *Salix* fluctuations are sometimes contemporary with very small peaks in fire activity (defined from all the charcoal curves except macros). If any fire activity did occur e.g. ground fires, this may have favoured *Betula* and *Salix* establishment in the disturbed areas at the lake edges. However, the charcoal concentration curve is much lower than maximum background levels and the low charcoal concentrations makes this appear unlikely.

Finally, there is a strong possibility that the changes could be related to the fluctuating climate, with *Betula* declines reflecting a reduction in temperature.

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Filipendula is a thermophilous plant whose climatic range coincides with the $14^{\circ}C$ July isotherm (Huntley and Birks 1983). Deteriorations in summer or annual temperatures may have caused short-lived reversions in the vegetation communities inhibiting *Betula* and *Filipendula* populations and favouring the re-establishment of *Salix* with an associated grassland understorey.

Comparison between the pollen profiles from NAQ, NM and the lake centre profile (D3) shows similar fluctuations in the pollen percentage curves. These changes may be varying according to regional climatic forcing which lasts for an estimated 30-100 years at a time. This is demonstrated by the similarities between the regional and lake edge pollen profiles shown in Figure 5.9. There is also considerable evidence for climatic oscillations during the first millennia of the Holocene (Huntley 1993, Walker 1995) and it seems logical to conclude that regional climatic impacts had a more important influence on the pollen rain than any localised impacts. However it is also likely that the observed pollen changes are due to a complex combination of inextricably linked processes, with climatic factors initially providing an overriding factor but with local environmental disturbance becoming an increasingly important factor as time progressed.

5.11.1.2 The Clay Band

The clay inwash band at 191-185 cm (> c. 9500 ± 70 ^{14}C yr BP, > c. 10,7125 cal yr BP) is likely to be due to a localised erosional event upon the island as there is no trace of the event further to the north or east of the island (Cloutman 1988a). The clay band is laterally and longitudinally discontinuous like the inwash stripes from the North York Moors (Simmons *et al* 1975). Unfortunately the pollen concentrations in the clay band were too low to enable pollen counts across the stratigraphic boundaries, thus hampering any comparisons with the work of those authors. It is difficult to imagine what type of process could explain a sudden increase in the water catchment area of the island so that it suddenly yielded a large abundance of mineral sediment in a discrete phase. Substantial deforestation, runoff, soil erosion and flooding can be ruled out as there is only a small but insignificant decrease in tree pollen prior to the inwash event. The presence of microscopic charcoal at the beginning of the event could still be attributable to local hunter-

gatherer activities, although the majority of the charcoal deposition post-dates the erosional episode.

5.11.2 Early Mesolithic Fire Phases 1 a-1d >c. 9570 ±130 ^{14}C yr BP

Fine resolution sampling was undertaken to investigate the period of high charcoal deposition between 185.5-179 cm, with each sample representing c. 4.2 years of pollen deposition (Section 5.6). Due to the calcareous nature of the sediments in this part of the profile, no radiocarbon dates have been obtained to date the occupation phase. However, the radiocarbon date at 164-166 cm places this period of occupation sometime prior to 9570±130 ^{14}C yr BP (i.e. >11,062; 11,015; 11,012; 10,943;10,842; 10,829;10,786 cal yr BP) or > c. 9500±70 ^{14}C yr BP (> c. 10,7125 cal yr BP) using Dark's (1998; 2000) date for the *Dryopteris filix-mas* rise.

5.11.2.1 The Nature of any Vegetation Change

Charcoal concentrations are consistently high throughout the fine resolution sampling period suggesting continuous charcoal deposition/fire activity over a long period perhaps >100 years.

Pollen deposition is very variable and appears to produce a saw toothed pattern in pollen production which is particularly evident in the birch, grass, sedge and fern pollen/spore curves (Figure 5.5). The relationship between the charcoal and vegetation curves is not consistent suggesting that no single predominant process is in operation. There is evidence to suggest that increases in charcoal deposition are sometimes linked to changes in birch and sometimes they are linked to changes in grasses and ferns but these deductions depend on the type of charcoal information/representation that is used (see Figures 5.10a-e). For example, peaks in the number of charcoal pieces <8800 μm^2 correlate with declines in the male fern pollen curves and occasionally rises in birch pollen whereas, peaks in the charcoal concentration curve and charcoal:pollen ratio produce a combination of vegetational responses.

Research by Whitlock and Millspaugh (1996) has highlighted several problems to do with the deposition and interpretation of microscopic charcoal curves and their

association with pollen data. They identified a time-lag of potentially >5 years between a catchment fire and charcoal deposition in the middle of the lake. With such a time-lag it is difficult to argue for any direct connection between the pollen and charcoal curves. However, the occasional appearance of reed charcoal and *Neurospora* fungi indicate burning at the lake edges and charcoal deposition within the reed beds at the lake edges is assumed to be fairly static and deposited within a year or two. Thus charcoal deposition is assumed to occur within the 4 year sample span under consideration.

It is difficult to ascertain the natural (baseline) levels of the pollen input in order to detect peaks or troughs in the data, as the natural levels of pollen appear from profile D (Chapter Three) to be in a gradually changing but dynamic state of equilibrium (BV). When heightened charcoal concentration levels coincide with inflated *Betula* values then Poaceae and *Dryopteris filix-mas* percentages typically decline either immediately after the fire or after a slight delay. Conversely, if birch values are reduced slightly, then fern and grass values tend to increase or peak. This would suggest an opening of the canopy in part, resulting in an increase in habitats suitable for grass and fern expansion. Woodland diversity does appear to increase in Phase 1a-d with the somewhat surprising appearance of *Fagus* pollen, as well as the appearance of heliophytic woodland-edge species such as *Sorbus, Sambucus, Crataegus* and *Prunus*. Nonetheless, these may not necessarily be associated with any disturbance to the woodland canopy as species diversity also increases in the fine resolution samples from the regional profile (Section 3.10).

It is very apparent that there is no consistent pattern to the changes throughout Phase 1a-d and that the degree of change is quite small. If any of these changes are caused by human action or fires and are not just attributable to background variation in pollen production, then the actual extent of vegetation change was fairly small scale, especially any changes to the tree canopy.

In Phase 1b to 1d *Betula* appears to have been particularly favoured by the occurrence of fire perhaps even expanding into disturbed areas. As *Betula* first flowers when it is 5- 10 years old (Grime *et al* 1991) the immediate response of the

pollen curve suggests that this is caused by an over-representation of birch pollen caused by a depletion in pollen from another species.

Throughout Phase 1a-1d (Figure 5.5) the male fern curve appears to decline in a reverse response to increases in the birch pollen curve. When the percentage of male fern spores is excluded from the Total Land Pollen sum, these increases are still apparent and must reflect actual changes in the spore abundance. *Dryopteris filix-mas* appears to have been severely disadvantaged by the initial Phase 1a of burning (Figure 5.10e) although in latter phases (Phases 1b-d) higher spore production often occurs following an influx of charcoal (Charcoal concentration and macro charcoal curves), but is suddenly curtailed as soon as another charcoal peak occurs. This would suggest an increase in spore influx permitted by removal of some of the surrounding vegetation, followed by a disturbance or breaking up of the male fern stands leading to decreased spore production. Sometimes spore recovery is gradual following a reduction in charcoal levels i.e. after c. 8 years and sometimes it is immediate i.e. after c. 4 years. Male ferns do not start to sporulate until they reach 6-7 years old (Grime *et al* 1991); if spore recovery is immediate (<6 years) this must be due to temporary damage to the plants, whilst longer recovery times may indicate that new ferns have had to become established. The reasons for these processes are addressed in Chapter Ten.

The pollen concentration data are of limited use in these analyses as the concentrations are responding to changes in sediment accumulation. The most significant vegetation disturbance is liable to have taken place at the lake and woodland edge, notably causing declines in grasses (probably *Phragmites*) and male fern as discussed above. Reductions in grass pollen inputs would cause the relative increase in birch pollen although it is possible that some of the birch pollen is derived from seedlings which are expanding into areas of open soil once colonised by *Dryopteris filix-mas*. Active burning of at least small areas of reedswamp as opposed to cutting or trampling is denoted by the presence of reed charcoal and *Neurospora* during Phase 1a and the beginning of Phase 1b (see Figure 5.5). The presence of *Neurospora* attests to the local presence of the fire.

Numbers of macro charcoal >8800 μm^2 increase when total numbers of smaller particles decline, and it is during these macro peaks that the human activity and low intensity fires are thought to have occurred (c.f. Pitkänen et al 1999). Mellars and Dark (1998:149-150) also note that the presence of macro and micro charcoal particles do not always coincide, possibly caused by differences in charcoal production when different types of vegetation are burnt. Little work has been done on the quantity and size characteristics of charcoal produced from burning different vegetation types (Patterson et al 1987), but Dark (1998) states that there are very distinct differences between the charcoal size particles produced from reed, fern and rushes. According to her results rushes and ferns produce fragile charcoal whilst reeds produce more robust charcoal particles.

Disturbance of terrestrial vegetation may also have occurred, indicated by the presence of ruderals, e.g. *Artemisia, Silene, Succisa* and flowering of shrubs and heliophyte tree species, e.g. *Sambucus, Prunus, Salix, Fraxinus* and *Fagus* (see Figure 5.5). From the pollen data, Phase 1a appears to have produced the most intense period of disturbance with fire/or human activities possibly causing reductions in male fern and birch. The appearance of *Fagus* is unexpected as it is thought to have been a late immigrant into Britain, not arriving until c. 1000 ^{14}C yr BP (i.e. 929 cal yr BP; Huntley and Birks 1983). However, small pockets of the tree species are likely to have occurred from an early date where conditions were favourable because *Fagus* can regenerate outside of its present geographical range (Grime et al 1991). *Fagus* occurs on a wide range of soils particularly acidic gravels, sands and sandstones, similar to the glaciofluvial deposits which underly No Name Hill. *Fagus* is well represented when grown locally (Jackson and Wong 1994) with pollen frequencies of ≥2% indicating local but sparse presence (Huntley and Birks 1983). It is therefore entirely possible that some isolated *Fagus* trees actually grew upon the island and their pollen grains were able to reach the lake edges during a phase of canopy disturbance at the edge of the woodland.

In conclusion, small changes to the birch, grass and fern pollen curves appear to be linked to changes in charcoal deposition. These changes do not follow any consistent pattern although this could be explained by multicausal factors and a

mosaic of vegetation alterations. At least some areas of reedswamp were burnt (either on purpose or by accident), shown by the presence of sporadic reed charcoal and *Neurospora* fungi.

5.11.2.2 Duration of Fires and Vegetation Disturbance

The sharply defined peaks in the high resolution pollen and micro-charcoal curves indicate that mixing of the deposits has been minimal, and if charcoal was deposited soon after burning, this means that local burning extended over a substantial period with several phases of particularly intense or frequent fires. The research undertaken by Whitlock and Millspaugh (1996) serves to caution the researcher when interpreting the microscopic charcoal curves, however, once deposited within the reedswamp at the lake edge, the charcoal is assumed to be static. If the charcoal is deposited within less than 5 years of the event, the 4.2 year sample resolution used here, should produce a very reliable indicator of past fire occurrence. The only problem that may occur is if there was a greater than 5 year delay between the fires and charcoal deposition at the lake edge. It is impossible to resolve this matter using the present data but in this particular case most fires are envisaged to be either small scale reedswamp fires or small domestic fires, and as a result there should be a negligible delay in charcoal deposition.

According to the charcoal data, Phase 1 of the human related fire activity occurred over a continuous period of approximately 108 ^{14}C yr. Within that 108 year period, the fire activity can be sub-divided into 4 different sub-phases lasting about 21-41 ^{14}C yr each, or 27 ^{14}C yr on average. There is no clear and consistent relationship between the charcoal and the vegetation curves, so inferences about the origin of the fires are hard to draw, although several suggestions have been discussed above. There were probably several different processes in operation at one time which will account for the inconsistencies in the vegetation patterns. Alternatively it must be recognised that the majority of charcoal may be derived from domestic fires with the occurrence of *Neurospora* and reed charcoal caused by a freak and accidental burning of the reedswamp. Pollen changes would then be attributable to non-fire related activities such as trampling, cutting or harvesting of the vegetation.

5.11.3 Early Mesolithic Fire Phases 2a-e. >c. 9570±130-c. 9000 ^{14}C yr BP

Charcoal deposition (>50-250 cm^2 cm^{-3}) continues almost continuously after 179 cm through to the top of zone NAQ-5. This period of charcoal deposition can be divided into 4 or 5 sub-phases depending on the charcoal data that are used (see Figure 5.4), The charcoal concentration curve alone, would suggest that there was not much fire activity as the peaks only just exceed maximum background levels of 150 cm^2 cm^{-3}. In contrast the macro charcoal curve suggests five fire phases.

In common with Phase 1, the fire activity seems to coincide with changes to the grass and fern curves and perhaps even willow to a small degree. Phases 2a-d coincide with peaks in grass and declines in ferns, whilst Phase 2e corresponds with peaks in Pteropsida and declines in grass and male fern (Figures 5.11a-e) Consequently similar processes are invoked to explain these changes (see Chapter Ten). The intensity or proximity of the fire activity may have diminished or moved away from the site after the Phase 1 occupations since charcoal concentrations fall below 250 x10^{-5} cm^2 cm^{-3}.

By the top of zone NAQ-5, Cyperaceae and *Typha angustifolia* values are starting to increase indicating the lake edges are now shallow enough to support sedge beds and reedmace. *Betula* values drop fairly sharply in this zone alongside a rapid increase in *Corylus* pollen. Similar changes are seen in the regional diagram (Profile D). At NAQ there is no obvious indication that a hiatus occurs in any other pollen taxa and so sedimentation is believed to be continuous. The date of 9570±130 ^{14}C yr BP (Beta-104482) for the start of the *Corylus* rise is taken tentatively to be correct, bearing in mind the large standard error for the sample. *Corylus* was apparently replacing *Betula* and *Salix* even along the lake shoreline.

5.11.4 Later Mesolithic Fire Phases 3 and 4 <c. 9000 ^{14}C yr BP

The rest of the profile is fairly typical of profile NM to the south of the island, with a transition to *Corylus* dominated woodland and the progressive infilling of the lake edge with its local plant successions. During zones NAQ-6 and 7 *Corylus avellana* values fluctuate significantly in association with peaks in charcoal concentrations. These two phases of fire activity (labelled Phase 3 and 4), imply a local and fairly

significant presence of later Mesolithic peoples upon the island. Charcoal levels during both phases reach 600×10^{-5} cm^2 cm^{-3} and are associated with the deposition of pieces of macro charcoal. This suggests that the fire is both local and intense or large scale.

Corylus avellana is the major victim of the fire, with Cyperaceae (at least at first) and ferns (especially *Thelypteris palustris* i.e. marsh fern) appearing to benefit from any burning (Figures 5.11f-h). This is contrary to suggestions that *Corylus* forms a 'fire climax' vegetation (Smith 1970, 1984) and that later Mesolithic peoples burnt the vegetation purely in order to promote hazel in order to harvest its nuts. It seems more likely from this limited evidence, that fire was used to open up the forest canopy, increasing the diversity of the understorey and/or to promote the growth of lake side vegetation such as Cyperaceae. The pollen evidence from NAQ also supports a modest increase in grasses during Phase 4. Simmons and Innes (1996a:183) concluded that *"the emphasis on hazel (Corylus avellana) as an object of vegetation management may need to be supplemented by that of the encouragement of a grassy groundflora in what was a mostly wooded environment"*. Confirmation of the actual burning of vegetation (deliberate or otherwise), as opposed to domestic origins for the charcoal, comes from the presence of *Neurospora* and microscopic rush charcoal at 148 and 152 cm respectively (Figure 5.4). The apparent increase in *Pinus* pollen coincident with or succeeding the fire phases is believed to be an artefact of preferential preservation and the ease of identification and not caused by a post-fire pine expansion.

Ulmus and *Quercus* pollen is very sparse in profile NAQ, which is attributed to the poor preservation of the sediments in this zone and not a real reflection on the vegetation composition. It is assumed that low levels of elm were present at this time as indicated by the superior preservation in the sediments at NM to the south. The top of the profile is estimated to date to c. 8250 ^{14}C yr BP based on comparison with profile NM (i.e. 9263, 9167 or 9152 cal yr BP). Fire Phases 3 and 4 can thus be dated to approximately 8700 and 8600 ^{14}C yr BP respectively (i.e. c. 9677-9629 cal yr BP and c. 9545 cal yr BP).

5.12 NAQ Human Impact Test 2 - 95% Confidence Limits (IV)

5.12.1 Early Mesolithic ≤9700 – 9000 ^{14}C yr BP

From Section 5.11 above it can be seen that the main species thought to be associated with human impact in the early Mesolithic (zone NAQ-5, including the fine resolution phase) are:- *Betula, Dryopteris filix-mas,* Pteropsida (monolete undiff), Poaceae, and *Salix*. Whilst smaller changes in ruderals are also thought to have occurred. This section tests whether the pollen changes are larger than the inbuilt variability in the pollen counts themselves.

Figures 5.12 and 5.13 show the inherent variability (IV) in the percentage pollen data for all species. The diagrams, which show the 0.95 confidence intervals of the pollen and spore data, have been computed and plotted using PSIMPOLL (version 4.01) (Bennett 1992, 1994, 2002).

In Figure 5.12 *Betula, Filipendula, Dryopteris filix-mas,* Pteropsida (monolete) undiff, Poaceae, Cyperaceae and *Salix* all show pollen fluctuations that exceed the 0.95 confidence intervals. The remaining species are either persistently within the 0.95 confidence intervals or their values are too low to enable meaningful statistical analyses. During the fine resolution phase (Figure 5.13), only *Betula, Dryopteris filix-mas* and Pteropsida (monolete undiff) and exceed Cyperaceae the 95% confidence intervals at any time. The fluctuations of the remaining species are once again either persistently within the 0.95 confidence intervals or values are too small and preclude analyses.

Figures 5.14a-g show the pollen percentage diagrams for these species during the early Mesolithic (Zone NAQ-5). A 'best fit' regression line or curve has been plotted to show the mean trend in the vegetation throughout the zone i.e. the approximate trend in the vegetation before any human impacts. More complex regression statistics could have been used but the software was unfortunately not available. The mean value for the 0.95 confidence limits (IV) has also been plotted either side and the values are shown on the diagrams. From the diagrams it is easy to assess which parts of the pollen diagrams exceed the mean 95% confidence limits. Figure 5.15a-f shows the same information but plotted only for the fine resolution

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sampling phase, where the slope of the regression line is different, as the samples have been taken over a smaller time interval.

From the diagrams it is possible to identify samples where the pollen curves are higher or lower than would be expected, if they were to follow the natural background trend. This method has been found comparable to analysis of the diagrams by eye, but is able to show the periods of change with increased clarity.
To eliminate any inconsistencies between the two methods, the diagrams (Figures 5.14.and 5.15) have been checked against Figures 5.12 and 5.13 (95% confidence limits from PSIMPOLL).

The periods of significant vegetation change are shown in Figures 5.14 and 5.15. These can then be compared to the charcoal curve to see if they coincide with periods of charcoal deposition, as summarised in Table 5.5.

Table 5.5   Significant changes in pollen and spores during the early Mesolithic compared with charcoal deposition

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal conc. pattern
Pteropsida	All	All	Mixed response all Phases
Dryopteris filix-mas	All	All	Peaks mainly cause declines in spores-most Phases
Betula	202		Pre Phase 1 decline
	200-197		Pre Phase 1 peak
	192		Pre Phase 1 decline
		191-187	Pre Phase 1 decline
	Fine resolution 184.63	Fine resolution	Phase 1a decline
		184.35	Phase 1a peak
	182.13		Phase 1a peak
	180.63		Phase 1c peak
	179.13		Phase 1d peak
Poaceae		202	Pre Phase 1 small peak
		200-199	Pre Phase 1 small peak

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal conc. pattern
Poaceae	196		Pre Phase 1 peak
		193	Pre Phase 1 small peak
		176	Phase 2a peak
	174		Phase 2b peak
	172		Phase 2c small peak
		168	Phase 2e peak
Salix		202	after Pre Phase 1 peak
	201		Pre Phase 1 decline
		200-199	Pre Phase 1 peak
	197-194		Pre Phase 1 decline
		193-192	Pre Phase 1 peak
	Fine resolution 182.13		Phase 1a peak
		176	Phase 2a peak
Filpendula	202		after Pre Phase 1 peak
	200		start of Pre Phase 1 peak
	168		Phase 2e peak
Cyperaceae	Fine resolution 183.0	Fine resolution 180.13 179.13	after Phase 1a peak start of Phase 1c peak Phase 1d peak
		176	Phase 2a peak
	175		Phase 2a decline
	164-62		Phase 2 decline then small peak
		161	Phase 2 small peak

Table 5.5 reinforces the conclusions reached in Section 5.11 during the conventional analyses of human impact, but in addition it also highlights other taxa that were overlooked, e.g. Cyperaceae.

The pollen outputs from all the species (above) fluctuate in excess of the limits that could be expected due to inherent variability in the pollen counts. Pteropsida (monolete) undiff. and Dryopteris filix-mas values in particular, exceed expected

levels throughout nearly all of the early Mesolithic. This suggests that the spore percentages have been affected by more than just internal percentage variations. The contemporaneous deposition of charcoal particles suggests that human activities are occurring concurrently and may be responsible (in whole or part) for these changes in the vegetation. On the other hand, fluctuations do occur in the absence of large charcoal peaks, so background variability (BV) may also be a factor that needs to be taken into account. However, using this statistical test, the evidence supporting some form of human alteration to vegetation communities, especially ferns, appears to be fairly robust.

5.12.2 Later Mesolithic or < 9000 ^{14}C yr BP

In the later Mesolithic, human firing of the vegetation is thought to have affected *Corylus*, Cyperaceae, ferns and possibly grasses. By using the pollen confidence limits in Figure 5.12 it is possible to pick out times when the pollen levels exceed the expected variations caused by inherent variability in the pollen counts. These are illustrated in Table 5.6. No regression lines are applied to the data as the model proposed in Section 3.15 is no longer applicable.

Table 5.6 Significant changes in pollen and spores during the later Mesolithic compared with charcoal deposition

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal conc. pattern
Corylus	162		Species migration
	161		small Phase 2 peak
		156	start of Phase 3 peak
		152	Phase 3 peak
	148		Phase 4 decline
		144	Phase 4 peak
Poaceae	144		Phase 4 peak
Cyperaceae	160-156		start of Phase 3 peak
		152-148	Phase 3 peak and then decline
	136		Phase 4 decline
Pteropsida	152-136		Natural Hydrosere?

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal conc. pattern
Thelypteris palustris	152		Phase 3 peak
		148	Phase 3 decline

Some changes, such as the rise in *Typha angustifolia* and Pteropsida (monolete) undiff. are caused by the progression of the hydrosere, whilst others, such as the sharp rise in *Corylus* between 162-161 cm are caused by the arrival of the species. The huge peak in Pteropsida from 152-136 cm is also caused by deteriorating preservation conditions, which means the ferns can no longer be determined to species.

Once again the statistical test reinforces the conclusions reached in Section 5.11 and it seems likely that most of the sharp changes to the pollen curves (excluding hydroseral and immigration factors), are caused by human impacts.

5.13 NAQ Human Impact Test 3 – Background Variations and 95% Confidence Limits

Analysis of the regional background vegetation in Chapter Three has already established that the background variations in pollen production are fairly high, depending on the time window of analysis. Thus some of the apparent vegetation changes at NAQ that have been attributed to human impact may in fact be explained by natural background variations in pollen production. This will be tested in the following section for the early Mesolithic only, as that is the only period when the model applies.

In Figures 5.16 and 5.17, in addition to the confidence limits (IV), the expected background variability (BV) is also plotted on the figures. If the pollen fluctuations exceed the combined limits of BV+IV, it would seem probable that real changes to the vegetation are occurring. If these fluctuations are also accompanied by charcoal peaks then these changes can be confidently attributed to human actions.

The percentage BV value applied to the diagrams has been normalised from the

calculations in Chapter Three (see also Table 5.7 below). This has been done by making the lake edge background variation, a direct proportion of the background variations at the lake centre. For example the lake centre BV for *Betula* was ±5-7% for the early Mesolithic (zone D-5) and ±3.75-4.75% for the period of fine resolution sampling. As the pollen percentages in NAQ are up to 50% lower than the values at D3, the background variation (BV) has been lowered proportionately. Similarly, the lake centre BV for Poaceae was ±3.8-5% for the early Mesolithic zone D-5 and ±3.5-3.75% during the fine resolution phase. As the lake edge Poaceae values at NAQ are higher than the lake centre values the full BV% is applied to NAQ.

Table 5.7   IV and BV % calculations for various taxa from NAQ

Profile	Species	NAQ % IV	D3 % BV	NAQ % Range	D3% Range	BV Scaling factor	NAQ % BV	E%= $\sqrt{(IV^2+BV^2)}$
Zone NAQ-5	*Betula*	3.7	9	52-25	78-37	0.66	6	7
	Dryopteris filix-mas	1.65	4.2	0-18.5	0-9	1.00	4.2	4.51
	Poaceae	2.71	4.2	7-30	4-22	1.00	4.2	5.0
	Pteropsida (monolete) undiff.	2.79	5.28	4.7-34.7	0-11.3	1.00	5.28	5.97
	Filpendula	1.32	2.7	0-13	0.7-12	1.00	2.7	3.0
	Salix	1.26	3.1	0-8	1.3-10.2	0.8	2.48	2.78
	Cyperaceae	1.89	1.7	1-15	0-3.7	1.00	1.7	2.54
Fine resol'n	*Betula*	3.5	8.6	48-25	60-42	0.6	5.16	6.24
	Dryopteris filix-mas	1.93	3.2	3-18.5	0-8	1.00	3.2	3.7
	Poaceae	3.25	4.6	18-30	10-18	1.00	4.6	5.63
	Pteropsida (monolete) undiff.	2.76	3.56	4.7-33	2-10.5	1.00	3.56	4.5
	Filipendula	1.1	3.2	0.7-3.7	2.8-9	0.25	0.8	1.36
	Salix	1.37	2.1	2-6.5	2.4-6.6	1.00	2.1	2.5
	Cyperaceae	1.43	1.9	1-7	0.5-3.8	1.00	1.9	2.38

Figures 5.16 and 5.17 show the combined IV + BV limits for the selected taxa. Any fluctuations that are above the IV + BV limits providing they have also been identified in Tables 5.5 and 5.6, can then be confidently attributed to human influence.

5.13.1 Early Mesolithic Results

At several points on Figures 5.16 and 5.17, it is possible to say with statistical confidence, that the variations are in excess of sample and background variability and therefore they are probably the result of human activities (see Table 5.8). All such points are concurrent with a least some charcoal deposition and most are contemporary with charcoal peaks of $> 150 \times 10^{-5} \, cm^2 \, cm^{-3}$.

Table 5.8 Significant changes in pollen and spores during the early Mesolithic compared with charcoal deposition

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal conc. Pattern
Betula	202		Pre-Phase 1 decline
	200-199		Pre-Phase 1 peak
		191-187	Pre-Phase 1 decline
	Fine resolution 184.63	Fine resolution	Phase 1a decline
Dryopteris Filix-mas		195	Pre-Phase 1 peak
	Fine resolution 185.5 182.37 181.0 180.0-13	Fine resolution 182.13	After Phase 1a peak Phase 1a peak Phase 1a peak Phase 1b decline start of Phase 1c peak
	173		Phase 2b decline
	171		Phase 2d peak
		168-166	Phase 2e peak
	164		Decline
Poaceae		202	Pre Phase 1-small peak

Species	Peak (depth in cm)	Decline (depth in cm)	Charcoal conc. Pattern
Poaceae		200-199	Pre Phase 1-small peak
	196		Pre Phase 1 peak
		193	Pre Phase 1 small peak
		176	Phase 2a-peak
		168	Phase 2e peak
Pteropsida (monolete) undiff.	Nearly all	Nearly all	Nearly all Phases
Pteropsida (monolete) undiff.	Fine resolution 191-187 183.35-13 180.63	Fine resolution 185.5 184.63 182.13	Pre Phase 1 decline Pre Phase 1 peak end of Phase 1a peak Phase 1a peak Phase 1a decline Phase 1c peak
Filpendula	202		after Pre Phase 1 peak
	200		start of Pre Phase 1 peak
Salix		202	after Pre Phase 1 peak
	201		Pre Phase 1 decline
		199	Pre Phase 1 peak
	197-194		Pre Phase 1 decline
		193	Pre Phase 1 peak
	Fine resolution 182.13		Phase 1a peak
Cyperaceae	Fine resolution 183.0	Fine resolution 179.13	after Phase 1a peak Phase 1d peak
		176	Phase 2a peak
	164-62		Phase 2 decline then peak
		161	Phase 2 peak

Most of the pollen changes (except the fine resolution changes) defined in Tests 1 and 2, stand up to the background variability test, Test 3. That is, human activities are believed to have modified birch, male fern, ferns, grasses, sedges, willow and meadowsweet at certain points within the early Mesolithic. However during the

periods investigated with fine resolution analyses (Phase 1a-d), only fern and Cyperaceae populations were seriously altered by human activities, although birch and willow were also affected on single, but separate occasions. Even these variations (especially in *Betula*), are very small, and might not be significant if 99% confidence limits were applied to the data. Larger pollen changes may have been observable if the profile had been sampled closer to the early Mesolithic lake shoreline, however, 'in the field' preservation tests revealed that this was not possible.

5.14 Human Impact at NAQ: Conclusions

It seems apparent that human groups actually did alter the vegetation on the north side of No Name Hill at certain periods during the early Mesolithic and later Mesolithic:

Pre-Phase 1 – willow, meadowsweet, ferns, grasses and birch all vary in their response to possible human activities.

Phase 1a - birch declines, ferns fluctuate and willow and sedges peak

Phase 1b – male fern peaks

Phase 1c – ferns peak

Phase 1d – sedges decline

Phase 2 – grasses decline whilst male fern and sedges fluctuate and there is a small peak in hazel.

Phase 3 – hazel declines whilst marsh fern and sedges fluctuate.

Phase 4 – hazel fluctuates whilst grasses and sedges peak.

During the most intense periods of fire activity investigated from the early Mesolithic deposits these modifications to the vegetation were very small and only really had a significant effect on fern and sedge populations. The vegetation appears to have exhibited a complex response to human activities and fires.

The response from birch, ferns and meadowsweet is very variable and may not be a direct consequence of fire. On the other hand, grass and sedges seem to exhibit a consistent response, as they seem to decline with the occurrence of charcoal peaks.

The response of willow also appears to be consistent, with willow pollen declining with charcoal peaks and then increasing afterwards. These three taxa may then be directly linked to the production of charcoal. This is supported by the sparse occurrence of reed and rush charcoal within the profile and the presence of *Neurospora* fungi which indicates localised burning. There is also tree-ring evidence for the coppicing of willow or poplar on the north side of the island (Rowena Gale *pers com.*), but as the wood has not been dated, no direct link with the observed pollen changes can be made.

During the later Mesolithic burning of the reedswamp probably took place on a small scale, causing fluctuations in populations of ferns, sedges, grasses and rushes, and causing the production of *Neurospora* fungi and deposition of microscopic rush particles. Stands of hazel may also have been locally affected by the fires at the lake edges. Alternatively, the amount of hazel pollen reaching the lake varies depending on the density of the surrounding vegetation.

5.15 Comparisons of NAQ with Star Carr

The nature, duration, intensity and timing of any vegetation disturbance at No Name Hill will be compared and contrasted with the changes at Star Carr in Chapter Ten and thus will not be discussed further within this chapter.

5.16 Comparisons of NAQ with other lake edge profiles from the Vale

Profile NAQ is very similar to profile NM to the south, with the exception of the vegetation changes caused by human activities. The only notable difference is the much lower percentages of *Betula* pollen at NAQ compared to NM but this is explicable by the higher influx of pollen from local wetland grasses, e.g. *Phragmites*. Because profile NM and NAQ are so similar, only unique differences between NAQ and the other lake edge deposits will be discussed in this section.

The most significant difference is the sharp decline in *Betula* and the sudden rise in *Corylus* at the end of zone NAQ-5. This sudden rise in *Corylus* appears to have been particularly abrupt when compared with other lake edge sites, e.g. NM and Profiles

M1, M2 and Clarke's site (Mellars and Dark 1998), although it is similar in appearance to the rise recorded from Profile D at the lake centre. If the arrival of *Corylus avellana* and rise to 45% TLP is synchronous throughout the lake edges, then one must assume that either there is a hiatus at NAQ, or that sediment accumulation rates declined dramatically at 171.5 cm.

The *Pinus* pollen curve at NAQ also suggests the local presence of this tree shortly after the rise in *Corylus avellana* woodland, at an approximate date of 8700 ^{14}C yr BP. This is about 500 years prior to the presence of pine at NM just 250 m to the south (Chapter Four). However, closer inspection of the pollen concentration curve from NAQ reveals that *Pinus* pollen levels are only one third to one quarter of the values attained in the early Mesolithic. The misleading pollen percentages (up to 25% TLP) are likely to be caused by the corrosive-resistance of the pollen grains in these drier sediments and not due to any local pine presence at that time. High concentrations of *Pinus* pollen, along with pollen of most other types, are found at the transition from organic muds to reedswamp at 171-170 cm (see Figure 5.8). This provides further support for Walker and Godwin's (1954) theory of a strandline of pollen forming at the lake edges.

So far there is no evidence to suggest any local presence of *Populus* on No Name Hill, although the poor pollen dispersal and small surface area of the lake edge would make pollen representation unlikely in any case. Pollen from *Ulmus* and *Quercus* are virtually absent at NAQ but this is probably due to pollen preservation biases and not a reflection of the local vegetation. The low representation of willow pollen at NAQ (in relation the high values at Star Carr) appears to be a function of sample distance from the lake edge. Cloutman and Smith (1988) and Day (1998) have both demonstrated that willow carr occurred in a very specific belt at the lake edge with significant concentrations of pollen occurring in a very limited zone of perhaps only 5-10 m.

The higher lake levels proposed by Walker and Godwin (1954) and Cloutman (1988a) for the period 9500-9000 ^{14}C yr BP are not readily detectable in the pollen diagram from NAQ. However, there is some stratigraphic evidence to support a short-term rise in water depth between 181-177 cm, which may date to

approximately 9500 ^{14}C yr BP. If lake levels did rise at this time then the water rise was not substantial and probably lasted for less than 100 years.

5.17 Wider issues

Small fluctuations in aquatic taxa, e.g. *Nymphaea alba*, *Sphagnum* and *Pediastrum* at NAQ provide some limited evidence for fluctuations between wetter and drier conditions during the first millennia of the post-glacial (Bohncke and Vandenberghe 1991). This feature has already been noted from the regional pollen diagram in Chapter Three and will be discussed further in Chapter Eleven when more evidence has been accumulated.

5.18 Chapter Five – Summary

The main findings identified from this chapter are:

- The 2.5 mm (4.175 yr) fine resolution samples from NAQ are comparable to the 4.05 yr sample resolution from the lake centre deposits in Chapter Three.

- The irregular nature of the charcoal and pollen curves reinforces the hypothesis that there was no mixing of the lake edge sediments. These findings support the application of fine resolution analyses.

- There are at least four (maybe five) phases of fire activity. Each phase can be split into sub-phases, which are of differing intensities and durations (see Figure 5.4).

- Once again, the reedswamp was burnt on at least five occasions, identified from the sporadic remains of microscopic rush and reed charcoal.

- The pollen data were subjected to a three-stage test for Human Impact, using the methodology outlined in Chapter Three.

- Most of the pollen changes attributed to human activity, stood up to all three statistical tests.

- During the early Mesolithic human actions appear to have caused small changes to the vegetation, particularly fern populations. The response of the vegetation is however, very complex and variable.

- Alterations to the grass, sedge, rush and willow populations may have been directly related to fire activities, but changes to birch, fern and meadowsweet populations were probably not directly linked to the occurrence of fires.

- During the later Mesolithic hazel, grass, sedges, rush and marsh fern are thought to have been affected by human activities. Once again this involved burning of the reedswamp and fires may also have affected stands of hazel at the island edges.

Chapter Six – The Northern Lake Edge of No Name Hill

6.0 Introduction to Profile NAZ

The location of profile NAZ was determined following the discovery of dense lithic and faunal remains in a relatively 'wet' trench almost 20 m to the southwest of trench NAQ, and nearer to the island edge (Figure 6.1). Profile NAZ was retrieved in order to provide supplementary information about the vegetation changes that took place along the northern lake edges during the early Mesolithic. NAZ should also enable correlation and dating of some of the vegetation changes at NAQ (Chapter Five) with the concentration of archaeological artefacts from the northern lake edge. In theory, by sampling the pollen rain 20 m closer to the shore, should be possible to obtain more detail and information about the vegetation disturbances and their scale or intensity in relation to similar profiles obtained from Star Carr. Lastly, NAZ should provide information about the spatial deposition of charcoal particles and the local versus extra-local periods of human occupation along the northern edge of the island.

6.1 Sampling

A single monolith tin was retrieved from an open 2x2 m trench, approximately 8 m to the north of the early Mesolithic shoreline which is estimated to occur at 24.5 m OD (Figure 6.1). The trench contained several archaeological artefacts including an antler from a culled red deer. The monolith was cut from the cleaned south facing section of the trench and wrapped and stored in polythene prior to analysis.

6.2 Lithostratigraphy

Basal grey sands were overlain by a very thin band of grey clay that correlates to the clay band in profile NAQ. The clay was then overlain by lake muds, which were then superseded by reed peat with abundant macro remains. The sediments displayed the following detailed lithology, with all measurements taken from a datum of 23.34 m OD.

Depth in cm (Level m OD)	Description
0-23 (23.34-23.11)	Very dark brown crumbly reed peat with abundant *Corylus* remains
23-47 (23.11-22.87)	Dark brown lake detritus with macro remains of monocotyledons and *Betula*
47-48 (22.87-22.86)	Sticky grey clay layer with slate/manganese fragments (Context 9419)
48-50 (22.86-22.84)	Dark grey sand

6.3 Pollen and Microscopic Charcoal Analyses

Sub-samples of 0.5 cm^3 of sediment were taken for pollen and microscopic charcoal analysis at intervals of 1-4 cm throughout the profile. Samples were prepared according to the laboratory procedures outlined in Chapter Two and Appendix 1.

6.4 Radiocarbon Dating

Three samples were submitted for small sample (AMS) radiocarbon dating. The results of the AMS dating are presented in Table 6.2 below:

Table 6.2   **Radiocarbon Dates from NAZ**

Depth in cm (in m OD)	Lab Code	Radiocarbon yr BP	$\delta^{13}C$ (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
9-11 (23.24-23.25)	Beta-104486	8850±50	-25.8	10,106; 10,091; 9914; (10,174-9689)	*Corylus avellana* nut
34-37 (22.97-23.0)	Beta-104485	9250±60	-28.7	10,472; 10,457; 10,425; (10,636-10,239)	*Betula* wood

Depth in cm (in m OD)	Lab Code	Radiocarbon yr BP	$\delta^{13}C$ (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
46 (22.88)	Beta-104484	9510±60	-26.4	10,740; (11,108-10,580)	Red deer antler (Context 9420)

6.5 Zoning the Diagram

The percentage pollen diagrams (Figures 6.2-6.4), have been divided into two local pollen assemblage zones (LPAZ), using the zonation program CONISS (Grimm 1986). The pollen zones have been compared to the regional profile D (Chapter Three) and numbered accordingly.

6.6 The Palaeoecological Sequence

Pollen concentrations and preservation levels were very low, reflecting the unsaturated post-depositional environment. This is also why there is a low density of the sample points within the pollen diagram. The resulting pollen zones have been identified as:

Early Mesolithic > c. 8800 ^{14}C yr BP

LPAZ NAZ-5   47-22 cm   *Betula-Corylus avellana-Dryopteris filix-mas*

LPAZ NAZ-6   22-10 cm   *Corylus avellana* - Cyperaceae- Pteropsida (monolete) undiff.

The pollen assemblages are described in Table 6.1.

6.7 Interpretation of the Radiocarbon Dates

Beta-104484 was cut from the very base of a red deer antler, which had been found in the basal sediments of trench NAZ. The antler was unshed and showed signs of utilisation (possibly for barbed points), demonstrating that the deer had been killed

by hunter-gatherers. If the antler could be stratigraphically correlated to the pollen diagrams at NAZ and NAQ, then dating of this artefact would provide a *terminus post quem* 'date after which', for that period of human activity on the island. Unfortunately, the $\delta^{13}C$ of : –26.4‰ clearly shows that the collagen extracted from the antler has been contaminated by humic and fulvic acids from the encompassing organic layer. Housley (1998:18) states that, *"The determination is unlikely to be an accurate indication of the age of the antler"*.

Nonetheless, as the antler lay on top of the basal and primarily inorganic sediments, then 9510 ±60 ^{14}C yr BP must provide a minimum age for the antler. In addition, the antler was found just below the thin band of grey clay in profile NAZ. As the clay band can be traced stratigraphically northwards and correlates with the clay band at NAQ, then the antler must pre-date Phase 1 of the episode of human occupation at NAQ.

The second sample, Beta–104485, was taken to provide an approximate date for the rise of *Corylus avellana* on the island. As the sample of wood was taken from a level just after the beginning of the hazel rise, the date of 9250±60 ^{14}C yr BP should slightly post-date the arrival of hazel at the lake edge. Despite this, Beta-104485 is statistically indistinguishable from the dates of 9255±135 ^{14}C yr BP for the hazel rise at Flixton AK87 (Innes 1994; Simmons *et al* submitted), and 9385±85 ^{14}C yr BP for the hazel rise at Star Carr (Day and Mellars 1994).

The third and final date, Beta-104486 was derived from a hazelnut, taken from close to the top of the monolith tin. It provides a date of 8850±50 ^{14}C yr BP for the top of the pollen diagram, sometime after the arrival of hazel. According to Housley (1998) there is no reason to doubt the validity of the second and third radiocarbon dates.

6.8 Sediment Accumulation Rates

Using the mid-point of the dates provided by samples Beta-104485 and Beta-104486, it is possible to work out the approximate rate of sediment accumulation

within the profile. This equates to 0.066 cm yr^{-1}. Providing the rate of sediment accumulation was constant throughout the profile, then organic sedimentation is calculated to have begun at approximately 9425 ^{14}C yr BP (10,635 cal yr BP) with the *Corylus* rise occurring at approximately 9320 ^{14}C yr BP (or 10,525 cal yr BP). The correlation between the clay bands at NAZ and NAQ means that most of the human activity recorded at NAQ should also have been registered within the sediments at NAZ.

If one or more of the two radiocarbon dates (above) lies outside of the mid-point of their standard error range, then the base of the organic profile could have started to accumulate anytime between c. 9210-9640 ^{14}C yr BP (c. 10,288-11,110 cal yr BP; within 95% confidence limits). The *Corylus* rise would then also occur sometime between 9162-9479 ^{14}C yr BP (10,243-10,726 cal yr BP), which is within an acceptable range when compared to other work from the Vale (see Section 6.7). Figure 6.5a plots the sediment accumulation rate in the form of a time-depth curve.

Figure 6.5a can be compared to the total palynomorph concentration curve presented in Figure 6.5b, as the latter can be a good indicator of the sediment accumulation rate. The fact that the pollen concentration curves (see Figure 6.7), rise and fall in unison suggests that they are being affected by variations in sediment accumulation. Figure 6.5b may therefore demonstrate that sediment accumulation rates were not constant at NAZ, with a particularly slow phase of sediment deposition at 24 cm and one particularly fast phase of sediment deposition at 39-40 cm. Unfortunately the wide intervals between radiocarbon dates do not allow this detail to be observed.

6.9 Pollen Preservation

Analysis of the pollen preservation curve (Figure 6.6- pollen preservation) can provide insights into the depositional and post-depositional processes that may have affected the pollen microfossils (Moore *et al* 1991).

6.9.1 Zone NAZ-5   47 cm-28 cm

Unidentifiable pollen accounts for between 10-12% of TLP. This sum is predominantly composed of corroded, crumpled and concealed grains and is mainly attributed to resistant organic matter and to a degree of oxidation and compaction in these fairly shallow peats from the lake edge. The small peak in corroded pollen at 40 cm was probably caused by depositional conditions at the time of sediment formation, perhaps seasonally dry conditions or burning.

6.9.2 Zone NAZ-6   28 cm-10 cm

Unidentifiable grains gradually rise from c. 12- 23% TLP. Corroded and crumpled grains increase significantly towards the top of the profile demonstrating irreversible oxidation of the shallow peat deposits. The total pollen concentration curve at NAZ declines from c. 275,000 grains cm^{-3} at 24 cm to c. 50,000 grains cm^{-3} at the top of the profile. This is a distinct reduction when compared to the total pollen concentrations in Profile D (Chapter Three), implying that the pollen concentrations in NAZ have been seriously depleted as a result of drying and oxidation processes.

The low percentage of broken grains distributed throughout the profile indicates that erosion and reworking of the deposits was minimal.

6.10 The Charcoal Record (Figure 6.4)

Throughout the sediment profile, charcoal concentrations continually exceed the background concentration levels of c. 150 $x10^{-5}$ cm^2 cm^{-3}, with concentrations generally in excess of 250 $x10^{-5}$ cm^2 cm^{-3}. The charcoal concentration curve and the macro charcoal curves (>8800 μm^2) in particular, show a triple peak in charcoal deposition presumably caused by localised fire activity. This fire activity also appears to have caused perceptible changes to the pollen inputs of some species, e.g. peaks in *Corylus* and *Aster* type pollen, and is probably attributable to the human activity which has already been identified at NAQ. During the charcoal peaks the charcoal concentration levels are well in excess of the levels recorded at NAQ, by up to 1.5-3 times as much. The deposition of charcoal in the intervening periods, is also generally in excess of background levels at c. 250 $x10^{-5}$ cm^2 cm^{-3},

and may also reflect human activity reasonably nearby and probably upon the island itself.

Peaks in the Charcoal:pollen ratio generally exceed 65 $\times 10^{-9}$ cm^2 $grain^{-1}$, which is about 1.5 times as much as the values obtained at NAQ during the early Mesolithic. This demonstrates that the deposition of charcoal particles drops dramatically (almost exponentially) over a horizontal distance of just 30 m.

In contrast to the triple peak of the charcoal concentration curve, the Charcoal:pollen ratio curve exhibits a quadruple peak in values. Considering the peak at 39 cm also coincides with a period of very low pollen concentrations and very poor pollen preservation, the charcoal peak is presumed to be an artefact of the data and not a true reflection of the magnitude of fire activity. Fires probably did occur, but as some pollen may have been lost due to poor preservation conditions, the deposition of charcoal is unlikely to have been so dramatic.

The charcoal record at NAZ therefore reflects three or potentially four periods of local *(in situ?)* human activity over a period of approximately 700-800 years.

6.11 Charcoal Identified to Species and Microscopic Fungi (Figure 6.4)

The occurrence of Type 173A, 173B, 201, and *Geoglossum* fungal spores (van Geel *et al* 1989) indicates that organic deposition began within an alkaline lake environment. *In situ* hummock and pool vegetation, consisting of *Equisetum*, *Carex* and *Phragmites* was already beginning to develop at the base of the sequence and so by 23 cm (23.11 m OD), nearer the top of the profile, the depositional environment had progressed to one of relatively dry terrestrial peat. Ascospores of *Gelasinospora* at 10-13 cm (23.21-23.24 m OD) denote the presence of dead wood in close proximity to the sampling site and are also possibly linked to the occurrence of carbonised wood remains (Jeff Blackford *pers com.*). In addition, two specimens of coprophilous *Sordariaceous* ascospores at 13 cm (23.21 m OD), suggest that animal or human dung was deposited nearby. Both types of fungal spores occur during peaks in the Charcoal:pollen ratio and during the deposition of macro charcoal pieces (>8800 μm^2), which provides further

evidence for human agency as a cause for the fire activity. Slightly lower down the profile at 24 cm (23.10 m OD), during another period of human linked fire activity, the deposition of microscopic wood charcoal provides direct evidence for the combustion of woodland vegetation (either directly or within domestic fires).

6.12 Synthesis and Human Impact Test 1 – Conventional Interpretation of Profile NAZ

This profile records the vegetation change at the northern lake edge from approximately the middle of the early Mesolithic to the beginning of the later Mesolithic i.e. a time-span of approximately 700-800 ^{14}C yr. Retrieval of information about the vegetation is low, due to the large sample intervals between pollen samples and the poor pollen preservation which has often precluded species analysis or caused some grains to become preferentially destroyed. However, the charcoal curve provides valuable data about the reduction in charcoal concentrations over distance and some attempt to correlate between fire phases at NAZ and NAQ should be possible.

6.12.1 The Mid -Early Mesolithic c. 9640–9250±60 ^{14}C yr BP

Sedimentation occurs within very shallow water with small amounts of *Nymphaea alba* and only sporadic amounts of the shallow water algae *Pediastrum*. Deposition begins on top of a grey clay layer with abundant slate/manganese fragments which can be correlated to the clay layer in profile NAQ. An antler taken from sediments slightly below the clay layer has been dated to 9510±60 ^{14}C yr BP (10,740 cal yr BP), giving a minimum date for sediment formation, as discussed in Section 6.8. Directly above the clay layer in NAQ there was a prolonged period of hunter-gatherer occupation and thus the sediments at the base of NAZ should correlate with this time. Using calculations from Section 6.8, the base of the profile is estimated to date to sometime between c. 9210-9640 ^{14}C yr BP (c. 10,288-11,110 cal yr BP) within 95% confidence limits, and should still record Phase 1 activity at NAQ.

The vegetation change is fairly typical of the region for this time. Sparse *Betula* woodland with small amounts of *Salix* forms the dominant vegetation type with *Dryopteris filix-mas* understorey. *Betula* pollen inputs are relatively low between 40-50% TLP, reflecting the contribution of the local wetland vegetation. The majority of the Poaceae pollen is composed of grains less than 26 μm in size, indicating that most of the pollen is probably derived from stands of *Phragmites* (Faegri *et al* 1989), although a small proportion of the pollen will also have derived from dry land grasses.

The first Charcoal:pollen ratio peak occurs at the very bottom of the profile at 46.6 cm and is recorded using all forms of charcoal measurement. This charcoal peak should be contemporary with Phase 1 at NAQ as it occurs directly above the clay band, which can be traced stratigraphically to NAQ. Analysis of vegetation change is hampered by low sample resolution but there appears to be little noticeable change in vegetation types and in particular few occurrences of ruderal pollen. The only visible reflection of human/fire disturbance is the presence of a few grains of *Isoetes lacustris* at 45 and 46.6 cm. Vuorela (1980) states that *Isoetes* species can be used as a proxy indicator of human disturbance because human activity results in the delayed input of inorganic material into a lake, creating ideal conditions for *Isoetes* to flourish.

Further up the profile at 41 cm, the increase in *Betula* pollen is interpreted as a region-wide natural increase in the species abundance and/or pollen productivity, although the low sample resolution makes it hard to draw any firm conclusions. Just below at 40 cm this there is a second peak in the Charcoal:pollen ratio, at the very beginning of the rise in *Corylus avellana* type pollen. The immigration and establishment of *Corylus avellana* is very gradual and has been dated to just before 9250±60 ^{14}C yr BP (Beta-104485; 10,472-10,425 cal yr BP).

Charcoal peak 2 corresponds to a small decline in Poaceae, Cyperaceae and a peak in *Dryopteris filix-mas*. This is consistent with subtle disturbance of the lake edge vegetation, potentially by fire. Some areas of disturbed ground occur on the dry land as indicated by the appearance of pollen of *Senecio* type, *Rumex* undiff and *Valerianella,* but it is uncertain whether these are merely natural occurrences or the

direct result of human activity. This period of activity probably occurred c. 9320 ^{14}C yr BP (or 10,525 cal yr BP), using sediment accumulation rates. The low quantities of charcoal particles and negligible amount of macro charcoal ≥8800 µm^2 at 40 cm in NAZ would be hard to explain if this was a very local fire event, however the high Charcoal:pollen ratio deposition is probably caused by low pollen preservation as discussed in Section 6.10. In reality any charcoal probably originated from an extra-local event (potentially Phases 2 from NAQ), which would explain the low numbers of charcoal particles at NAZ and NAQ, and the purely subtle changes to the vegetation. This would also explain the lack of *Neurospora* fungi at this point.

6.12.2 The late-early Mesolithic < c. 9250±60-885 ±50 ^{14}C yr BP

A third peak in charcoal occurs at around 24-20 cm during the rapid regional expansion of *Corylus avellana*. Using the estimates of sediment accumulation calculated in Section 6.8, this charcoal peak occurs at c. 9075 ^{14}C yr BP (10,221 cal yr BP) which is statistically indistinguishable from the date of 8940±90 ^{14}C yr BP (10,170 cal yr BP) for the hazel expansion at Star Carr (Day and Mellars 1994; Dark 1998; Dark 2000).

The water had become increasingly shallower and was now beginning to support stands of lesser reedmace (*Typha angustifolia*). This coincided with a change in the pollen source area from mainly waterborne to mostly aerial pollen inputs, which means that any fire related changes to the pollen diagram are liable to be a result of very local or *in situ* vegetation changes.

This third period of fire activity coincides with a prolonged peak in the deposition of *Senecio* type pollen, potentially derived from hemp agrimony (*Eupatorium cannabinum*), the remains of which were found in abundance at Star Carr (M3-Dark 1998). The deposition of *Senecio* type pollen at levels in excess of 1% TLP suggest that human activity resulted in trampled areas on the dry land. A single piece of microscopic wood charcoal also provides evidence for the combustion of vegetation. *Corylus avellana* pollen levels are slightly inflated in relation to other species concentrations (Figure 6.8a). This suggests an increase in the flowering of

hazel or an influx of hazel pollen, caused by a reduction in other species (including possibly *Juncus* as it is not recorded in the fossil pollen record, despite being present at No Name Hill). Initial fire activity is also associated with a small decline in grass pollen and a peak in sedges potentially reflecting firing of the reedswamp (Figures 6.8b-c). Unfortunately the pollen concentration diagram appears to be responding to a slow-down in sediment accumulation, which makes any firm conclusions hard to draw.

As *Corylus avellana* continues to become established, the vegetation canopy becomes denser, restricting the amount of light to the understorey so that grasses, ferns and herbs decline and woodland shrubs are shaded out. The lake-side vegetation progresses from stands of reedmace, *Phragmites* and sedges, to drier land colonised by ferns c.f. *Thelypteris palustris*. The final charcoal peak occurs near the very top of the profile at c. 13 cm dated to around 8900 ^{14}C yr BP (c. 10,180 cal yr BP). This time, the occurrence of fires causes hardly any perceptible change in the pollen curves. There is a slight increase in *Corylus avellana* pollen (Figure 6.8a) coincident with burning but it is probably not representative of an actual increase in *Corylus* abundance, as the concentration curve (Figure 6.7) remains fairly static. Ascospores of *Gelasinospora* and *Sordariaceous* fungi denote the presence of dead and/or carbonised wood and the occurrence of dung in the near vicinity. This final phase of charcoal deposition was therefore probably attributable to domestic fires and did not involve any actual firing of the ground vegetation.

The top of the profile has been dated to c. 8850 ^{14}C yr BP (Beta-104486). The sheer abundance of hazelnuts and macro remains of *Corylus avellana* attest to the very local presence of this tree/shrub. The absence of large numbers of *Ulmus* and *Quercus* pollen, two species which would be expected to have a presence on the island by this time, is explicable by the preferential corrosion of their corrosion-susceptible pollen grains.

6.13 NAZ Human Impact Test 2 – 95% Confidence Limits

Section 6.12 has identified that the main species to be associated with human impact are: Poaceae and *Dryopteris filix-mas* in Charcoal Peak 2, *Senecio*, Cyperaceae and *Corylus* in Peak 3 and *Corylus* in Charcoal Peak 4.

This section tests whether these fluctuations are greater than the inbuilt variability in the pollen percentages. Figure 6.9 shows the 0.95 confidence intervals of the pollen and spore data. Any significant fluctuations in the pollen curves (i.e. in excess of the confidence intervals) are listed in Table 6.3 and compared to the deposition of charcoal. It should be noted that the low abundance of many species precludes them from the statistical analysis.

Table 6.3 Periods of human impact in the early Mesolithic at NM compared against charcoal deposition and 95% Confidence Limits

Species	Peak (Depth in cm)	Decline (Depth in cm)	Charcoal pattern	Possible Human Impact (Y/N)
Poaceae		40	Peak 2 (Charcoal:pollen)	Y?-extra-local
		20	Towards end of Peak 3	Y?
Dryopteris filix-mas	40		Peak 2 (Charcoal:pollen)	Y?-extra-local
		28	low	N- natural, competition
Cyperaceae		41	Peak 2 (Charcoal:pollen)	Y?-extra-local
		16	decline	N- natural competition
	10		End of Peak 4	Y? but small
Corylus	24		Peak 3	Y
	13-10		Peak 4	Y?

Species	Peak (Depth in cm)	Decline (Depth in cm)	Charcoal pattern	Possible Human Impact (Y/N)
Senecio	24		Peak 3	N-Statistically insignificant
Filipendula		20	Towards end of Peak 3	N- natural, competition
Rumex	32		low	N- natural, disturbance
Typha angustifolia	24		Peak 3	N- natural, hydrosere
Pinus		41		N –*Pinus* not actually present
Pteropsida (monolete)	41		low	N-natural peak in ferns
		36	low	N- reduced preservation
	20		Peak 3	N?
		10	end of Peak 4	N?

The pollen confidence limits have helped to clarify the effects of human impact although, distinguishing between human effects, natural hydroseral changes and competitive interactions is sometimes problematic. Pteropsida and *Dryopteris* should also be considered together as changes in the abundance of one may be merely the result of changes in the conditions of preservation.

All three periods of potential human impact stand up to Test 2. However, it demonstrates that the peak in *Aster* is statistically insignificant, and that it is not possible to demonstrate that its appearance is related to human disturbance.

6.14 NAZ Human Impact Test 3 – Background Variations and 95% Confidence Limits

The model presented in Chapter Three is only valid for analysis of human impact in LPAZ zone-5 of the early Mesolithic. As stated above, it has not been possible to analyse the effects of any human impact during Peak 1, due to the location of the charcoal peak within the core and poor sample resolution. Peak 3 and 4 also occur during zone NAZ-6 and therefore fall outside of the relevant timeframe.

Charcoal Peak 2 on the other hand does seem to coincide with vegetation changes, although these are not believed to be local to the northern island edge. It can be seen from the pollen diagram that these changes are still fairly small and will not fall outside of the combined limits of BV and IV. For example the largest changes occur in Poaceae, but the combined BV and IV limits = ±5.58% (see Table 6.4 below).

Table 6.4   IV and BV % Calculations for Poaceae in Profile NAZ

Profile	Species	NAZ % IV	D3 % IV	NAQ % Range	D3 % Range	BV Scaling Factor	NAQ % BV	E% = $\sqrt{(IV^2+BV^2)}$
Zone NAZ-5	Poaceae	3.67	4.2	9-25	4-22	1.00	4.2	5.58

6.15 Human Impact at NAZ Conclusions

Fires caused by human activity result in the deposition of four charcoal peaks at NAZ (charcoal peaks 1-4). Peak 2 is thought to relate to extra-local fires, although these are still thought to have occurred somewhere on the island. Charcoal peaks 1, 3 and 4 are thought to relate to the occurrence of very local fires. Using the pollen diagram, it was not possible to determine whether humans altered the vegetation during Peak 1. Peaks 3 and 4 are both thought to relate to some form of vegetation disturbance. All the disturbances are summarised below:

Peak 1 (≥47 cm; < c. 9510±60 ^{14}C yr BP) – Effect is not possible to determine

Peak 2 (41-39 cm; c. 9320 ^{14}C yr BP (or 10,525 cal yr BP); c. 50 years) – Potentially extra-local reedswamp fires, resulting in a reduction in grasses, sedges and male fern.

Peak 3 (24-20 cm; c. 9075 ^{14}C yr BP [10,221 cal yr BP]; > c. 60 yr) – Local fires coincide with increased flowering of Hazel (coppicing?) and a decrease in grass

pollen, potentially reflecting firing of the reedswamp. Human activities may also have caused an increase in ferns (although the majority of this increase is probably related to natural hydroseral progression). Any peaks in sedges and *Aster* are statistically insignificant. Wood charcoal is also present.

Peak 4 (c. 13 cm; c. 8900 ^{14}C yr BP [c. 10,180 cal yr BP]; > c. 30 yr) - Probably locally occurring domestic fires. If there was any vegetational response it is confined to small increases in pollen from hazel and sedges. Dead and/or carbonised wood and dung occurred nearby.

It should be noted that the above analyses did not take into account any natural background variations (BV) in pollen output. If these variations were considered then, the effects of human impact would be considerably lower.

Peaks in charcoal concentration at NAZ are on average, between 1.5-3 times higher than the amount of charcoal deposited at NAQ (i.e. NAZ= 900-1800 x10-5 cm^2 cm^{-3}). This suggests that over a distance of 30 m there is an almost exponential decline in the amount of charcoal deposited from local fires. In this particular instance, (what are believed to be) very local fires, are exemplified by peaks in charcoal concentration 6-12 times higher than any regional background levels, during the early Mesolithic.

6.16 Comparison of NAZ with Star Carr

The low preservation levels and wide sample resolution at NAZ makes it rather problematic to compare NAZ with the detailed profile of M1 from Star Carr (Dark 1998). Profile M1, which was also taken c. 10 m from the lake edge, shows that willow percentages are comparable with those from NAZ. The occurrence of much higher willow percentages at M2 and M3, from Star Carr, from 5-10 m nearer the shore signifies that despite the low *Salix* pollen frequencies, a willow belt could still have been in existence at No Name Hill. The percentages for *Artemisia* are also much higher at M1 throughout the periods of human activity, supporting the hypothesis that there was lesser impact at No Name Hill.

Comparison between the fern curves is difficult due to the large proportion of spores from NAZ which have lost their distinctive coatings and have consequently had to be assigned to the Pteropsida (monolete) undiff category. However, superficial analysis supports the idea that deposition in profile NAZ began at or before 9500 ^{14}C yr BP. Comparing and contrasting the charcoal curves from the two sites demonstrates that both sites were repeatedly occupied, although at NAZ there were 3 phases of local occupation compared to the 2 (or potentially 3) phases of occupation at Star Carr (Day 1993; Day and Mellars 1994; Dark 1998).

By comparing and contrasting NAZ with the work of Cloutman and Smith (1988) from Star Carr, it was possible to establish that NAZ bears the greatest resemblance to profile VP85A/2. Both sequences show a similar pattern, range and abundance of pollen and fern types, suggesting that the water depth and location from shore was fairly similar. However, despite this close proximity to the lake edge, the levels of *Salix* c.f. *cinerea* pollen are still lower at NAZ than in VP85A/2, which leads to the assumption that the willow belt was not as extensive at No Name Hill. The significant difference in *Salix* pollen percentages between M1 (up to 10% TLP, Dark 1998) and VP85A/2 (up to 25% TLP) serves to demonstrate the very localised nature of the *Salix* pollen rain.

Finally, the relatively low *Betula* percentages at NAZ are a reflection of the abundance of the local wetland vegetation. At Star Carr birch values are even lower, implying that the environment was less wooded or that the willow carr and reedswamp was denser and/or more extensive, thus filtering out a higher percentage of the dry land pollen.

6.17 Comparison of NAZ with the rest of the Vale

The regional pollen diagrams (Chapter Three; Day 1996a), record much lower levels of pollen from *Aster* type species and higher levels of pollen from a range of woodland edge shrubs when compared with the results from NAZ. The high values for *Aster* type pollen at NAZ are explicable by the closeness of the pollen profile to the island edge, as well as the potential effect of human disturbance. Similar peaks in pollen from the Tubliflorae sub-family (which includes *Aster* type pollen), are

seen at Seamer Carr e.g. at CVIII just after the *Corylus* rise, although in the absence of charcoal evidence Cloutman (1988b) was not able to link these occurrences to human activity. The low abundance and diversity of woodland edge shrubs at NAZ could be a direct reflection of the lack of these species along the northern tip of the island. On the other hand, these pollen taxa generally have pollen grains which are susceptible to corrosion or which need identification of subtle surface markings. Unless such pollen grains are very well preserved, identification to species may not be possible. Therefore, bearing in mind the results from NAQ (Chapter Five), the low shrub diversity at NAZ is probably due to deterioration, crumpling or concealment of these important pollen grains.

Other significant features to note, are the negligible amount of *Juniperus* when compared to other profiles from the island (see Chapters Four and Five) and the complete absence of *Populus* at NAZ in the early Mesolithic when compared to other profiles from the region (Cloutman 1988b; Cloutman and Smith 1988; Dark 1998). However, considering the poor levels of preservation in NAZ this is likely to be a taphonomic bias and not necessarily ascribed to the absence of these two species.

6.18 Wider Issues

There is little evidence to support any large fluctuations in the lake levels at NAZ over the period c. 9500-8850 ^{14}C yr BP as proposed by Walker and Godwin (1954) and Cloutman (1988a). The only indication is a small decrease in *Typha angustifolia* at approximately 9300 ^{14}C yr BP (41-39 cm), otherwise all the species appear to be responding purely to the local hydroseral successions. If the water level did change around 9300 ^{14}C yr BP, then it resulted in only a modest and temporary increase in the lake level. Likewise, the gradual decrease in water level towards the top of NAZ is attributed to the local hydrosere progression and not thought to be caused by increased seasonality and aridity after 9000 ^{14}C yr BP (several authors cited in Tipping 1996).

6.19 Chapter Six - Summary

- NAZ was taken only 8 m from the early Mesolithic shoreline and should potentially provide a lot more detailed information about the vegetation changes and fires along the northern edge of No Name Hill.

- Wide interval sampling and the poor preservation status of the sediments, limits the amount of information that can be obtained about human disturbance. NAZ serves to illustrate that important palaeoecological evidence about human impact on or near the lake edges may have been lost over the majority of the ancient shoreline.

- Four phases of fire activity are still observable over a 700-800 year period.

- A red deer antler dates the bottom of the profile to > 9510±60 ^{14}C yr BP (10,740 cal yr BP), giving a minimum date for charcoal peak 1.

- Charcoal peaks 2-4 occur at approximately 9320 ^{14}C yr BP (or 10,525 cal yr BP); c. 9075 ^{14}C yr BP [10,221 cal yr BP]; and c. 8900 ^{14}C yr BP [c. 10,180 cal yr BP] respectively.

- From the available data these periods of fire activity seem to last between c. 30 to >60 ^{14}C yr.

- Charcoal Peaks 2 and 3 coincide with changes to the vegetation. Both phases potentially involve burning of the reedswamp but peak 3 also results in increased flowering of hazel (caused by coppicing?).

- Charcoal mainly appears to be related to domestic fire activity as it involves little vegetation change. There is also evidence for the presence of carbonised wood and dung nearby.

- Charcoal concentrations and numbers of macro particles decrease almost exponentially over a distance of 30 m.

- Very local fire activity (in this instance) produces charcoal peaks 6-12 times greater than background regional levels, from the same time period.

- Human impact was probably less intense at NAZ than at Star Carr, although both sites were repeatedly occupied.

- The 'apparently' low woodland-edge diversity at NAZ is attributed to taphonomic factors.

- There is little evidence to support any large fluctuations in the lake levels at NAZ over the 700-800 year period analysed.

- All the different fire phases from No Name Hill (NM, NAQ and NAZ) will be correlated and compared in Chapter Seven.

Chapter Seven - Comparing and Correlating the profiles from No Name Hill.

7.0 Considerations when Comparing and Correlating between different profiles

Caution must be exercised when attempting to correlate between sequences based on the changes in pollen types alone, as the pollen zones cannot be taken to represent exactly the same periods in time. The three sequences from No Name Hill (Chapters Four to Six) would have gone through different stages of succession at different times due to their varying proximity to the lake edge. In addition to these temporal and hydroseral differences, the three sequences would also have been affected by a range of taphonomic factors, mainly relating to pollen source area and preservation of microfossils. At NAZ the representation of insect pollinated plants would be expected to be higher as it is nearest to the dry land, as would the representation of low lying herb pollen (Sønstegaard and Mangerud, 1977; Jacobson and Bradshaw 1981). Whilst at NM (the furthest from the shore), one would expect contributions from canopy vegetation and extra-local vegetation to be higher (Tauber 1965, 1967; Jacobson and Bradshaw 1981). Representation of locally derived pollen grains also varies between sequences, especially grass and sedge pollen, which is often derived from the *in situ* reedswamp. This is shown by clumps of pollen grains, as clumps travel less distance than individual grains (GreatRex 1983)

Pollen preservation also becomes progressively poorer both upwards towards the top of the old lake surface and laterally towards the lake edge. This is reflected in the progressively drier deposits and the high numbers of undifferentiated fern spores, as well as the higher counts of the easily recognisable and corrosive-resistant pine grains. Consequently much of the information from NAZ has been lost due to differential pollen preservation, resulting in a pollen count with much lower species diversity.

Despite these differences, correlation between profiles is still possible. For example, regional vegetation changes on the dry land are likely to provide useful

and secure chronological markers that can aid the correlation between sequences, e.g. the regional rise in hazel. Correlation can also be achieved by using common stratigraphic horizons such as the clay band at NAQ and NAZ, and by the careful consideration of radiocarbon dates (providing they have a relatively small standard error and do not lie along a radiocarbon plateau).

Charcoal can also form an additional useful marker although correlation of different charcoal curves is not straightforward. A single period of burning would have involved a range of vegetation types, all with different degrees of combustibility (Umbanhowar and McGrath 1998). The production and deposition of the charcoal would also have been affected by a number of other factors such as fire temperature, wind speed and direction. Thus, the charcoal signature from a single fire is likely to look substantially different when viewed from different spatial locations.

7.1 Correlation of the three palaeoecological profiles
7.1.1 Using Regional Pollen Changes and Radiocarbon Dates
Despite the different pollen source areas and relative location of the sequences, the three pollen diagrams all exhibit remarkably similar patterns of general vegetation change. This is principally shown by the gradually rising and then declining birch curve, the gradual decline of juniper and meadowsweet, the bimodal fern curve and the arrival and rise of hazel, (although the bottom of all these pollen curves are truncated at NAZ).

As discussed in Chapter Three, the broad outlines and timing of the birch and the male fern curves are considered to be dominated by the effects of regional climatic forcing, although local effects are also superimposed upon this. These two curves therefore provide important horizons that enable correlation between sequences. The hazel rise provides another important marker. This rise is initially rather gradual, consisting of a period of low values followed by a greater increase. The arrival of *Corylus avellana* at No Name Hill has been dated to sometime between c. 9570±130 ^{14}C yr BP (at NAQ; Beta-104482) and 9250±60 ^{14}C yr BP (at NAZ; Beta-104485). The large standard error for Beta-104482 and the non-

contemporaneous sampling with the hazel rise means that both dates can be considered to be broadly contemporary, although it is true that there is a significant difference between the two dates (X2-test: df+1 T=5.0 [5% T=3.8]; Housley 1998:27). Any real difference in the arrival of *Corylus* pollen is likely to be attributed to the waterborne (regional input) of hazel pollen in the deeper water deposits, e.g. at NAQ. Nevertheless, the similarity between the dates for the hazel rise at Star Carr (Dark 1998:148) demonstrates that *"the hazel rise provides a valuable horizon for comparison between the sequences at the lake edge"* and by inference is also likely to be determined in part by the prevailing regional climate.

7.1.2 Using Charcoal Records

The charcoal records for the three profiles can be compared and correlated based on both the microscopic charcoal and macro charcoal (≥ 8800 μm^2) inputs, between and within the sequences. Before this can be done it is necessary to consider the source area of the charcoal particles of different sizes. A detailed discussion of the limited theoretical and experimental work on this subject has been undertaken in Chapter Two (Tables 2.2-4) so only the broad conclusions will be repeated here.

Diagrams of pollen-slide charcoal (defined by Clark (1988a) as 5-80 μm in diameter i.e. ≤ 6400 μm^2), are predominantly biased towards representation of charcoal from non-local fires, e.g. regional scale forest fires. However, charcoal dispersal from smaller fires is likely to be limited, e.g. from domestic hearths or burning of small areas of low stature vegetation (Bennett *et al* 1990b; Rhodes 1996; Dark 1998; Pitkänen *et al* 1999; Moore 1999). This is because the energy from the plume is unlikely to be able to inject the charcoal particles very high into the atmosphere. Thus, pollen-slide charcoal counts will contain a mixture of regional and locally derived charcoal. However, if most fires are derived from low stature vegetation, then pollen slide charcoal can reflect the local fire history better than the regional fire history (Pitkänen *et al* 1999).

If large peaks in the Charcoal:pollen ratio occur, they are likely to be associated with localised fire activity particularly if they are not contemporary with changes to the regional pollen rain and are associated with charcoal pieces ≥ 6400 μm^2.

Similarly, peaks in the numbers of macro charcoal pieces and charcoal concentrations in excess of regional 'background' levels are also likely to indicate fire sources nearby. The local source area of charcoal particles is also detectable by the identification of microscopic fungi (van Geel 1986; Boyd 1986; van Geel *et al* 1989) and the occurrence of characteristic cell types such as aerenchyma in the microscopic charcoal counts (Day 1991; Dark 1998).

Apart from the interpretational problems caused by variable deposition of aerial charcoal and secondary inputs caused by soil erosion, the waterborne transport of charcoal may also result in a time lag in its deposition (Clark 1988a; Whitlock and Millspaugh 1996). Nevertheless, when burning of *in situ* wetland occurs (as proposed here), or when firing is limited to the very small area of a hearth, then no water transport need occur, as once deposited the charcoal will remain *in situ* in the surrounding reedswamp or ground litter. The sheer fact that some of the microscopic charcoal is identifiable by its tissue type also denotes a fairly localised source area (Day 1991).

7.1.3 Correlation of the lake edge profiles from No Name Hill

Correlation between the different phases of fire activity at NAQ, NM and NAZ is listed in Table 7.1 (below) and illustrated in Figure 7.1.

Table 7.1   Correlation of charcoal events at NM, NAQ and NAZ

Possible Date of Occupation (^{14}C yr BP)	NAQ – 28 m North of island	NAZ- Northern lake shoreline	NM- 30 m south of No Name Hill
≥ c. 9510 ±50	Phase 1	Peak 1	Pre Phase 1
<9510 > 9100	Phase 2	Peak 2 < Peak 3	Pre- Phase 1
Between 9075- 8610±60	Phase 3	Peak 3	Phase 1
Between 8900- 8450	Beginning of Phase 4	Peak 4	Phase 2

7.1.3.1 ≥c. 9510±50 ^{14}C yr BP, (≥c. 10,740 cal yr BP)

The 1st charcoal peak (Peak 1) at NAZ (46.6 cm) is estimated to be contemporary with the very end of Phase 1 occupation at NAQ. Correlation is based predominantly on the clay band which links the two sequences and the fact that Phase 1 occupation at NAQ occurred directly after the clay horizon. Nonetheless, NAZ obviously does not record the whole of the occupation phase, probably due to low sample resolution.

The start of peak 1 NAZ and tail end of Phase 1 (NAQ) was estimated to have occurred at just after 9510 ^{14}C yr BP or around 10,740 cal BP. The occupation lasted for approximately 108 ^{14}C yr (using sediment accumulation rates) and consisted of four sub-phases of human activity of varying intensities. The elevated, but truncated, peak in macro charcoal particles at NAZ along with the high macro charcoal curve and presence of *Neurospora* and reed charcoal at NAQ, provide additional evidence that this was a localised fire event affecting the reedswamp and dry land at the north-western island lake edge. No contemporary fire activity occurred along the south side of the island at NM at this time.

7.1.3.2 c. <9510-9100 ^{14}C yr BP (c. <10,740-10,300 cal yr BP)

Phase 2(a-e) fire activity at NAQ (i.e. 9510-9100 ^{14}C yr BP; 10,740-10,300 cal yr BP), does not appear to correlate with any local fire events along the northwestern lake edge at NAZ (using present sample resolutions). This is particularly surprising as the sediments at NAQ register significant if somewhat sporadic macro charcoal peaks for sometime after Phase 1. Instead, Phase 2 fire activity at NAQ is thought to be the result of nearby (extra-local) fires upon the island. Charcoal Peak 2 at NAZ, occurring at c. 9320 ^{14}C yr BP (c. 10,520 cal yr BP) falls into this category.

The charcoal concentrations at NAZ and NAQ are both broadly equivalent during this time period, and range from c. 100-250 $\times 10^{-5}$ cm^2 cm^{-3} and a succession of extra-local fire events would explain these sporadic and higher than background levels of charcoal. The number and size of charcoal particles at NAZ and NAQ would then be composed of aerial and waterborne charcoal inputs from another point on the island. Extra-local fires would also explain the very low-key changes

to the pollen rain at NAZ and the lack of ascospores of *Neurospora* or fragments of charcoal identifiable to species. Profile NM, 250 m to the south also fails to register any significant fire activity during the equivalent time period although sporadic pieces of macro charcoal (>8800 μm^2 in NM Pre-Phase 1) provide support for the concept of fires elsewhere on the island.

If fires and human occupation did not occur along the north-western or southern lake edges of the island between 10,740-10,300 cal yr BP, then where else could the fire have occurred? Figure 7.2 shows the distribution of all the archaeological trenches upon the island. Trenches with *in situ* early Mesolithic finds are coloured in red. Research has shown the majority of macro charcoal pieces are deposited within tens of metres of low energy small scale fires (Day 1996a) and probably mostly within about 100-80 m (Rhodes 1996; Moore 1999). As the sediments at NAQ record about 300 macro charcoal particles (>8800 μm^2), this suggests that the fires could not have been much more than 80-100 m away. That is not to say that the location of the fires did not vary, as at times some of them must have been reasonably close to the southern shoreline to produce a weakened signal at NM. Figure 7.2 illustrates that if the Phase 2 fires recorded at NAZ and NAQ had actually originated from activity areas on No Name Hill, then they must have occurred along the western side of the island between LC and BJ where there were several concentrations of finds.

Alternatively, the fires may have been lit away from areas of human activity and could therefore have occurred along the eastern side of the island or in-between activity areas in the north and west. Such an approach is in keeping with hunting strategies where reedswamp is burnt to promote lush growth, which will provide attractive browse for game. However, such areas are unlikely to have been located near to sites of human occupation which would suggest that No Name Hill was not permanently occupied at those times.

7.1.3.3 Between c. 9075 to 8610±60 ^{14}C yr BP (10,220 to 9547 cal yr BP)
The third charcoal peak (Peak 3) at NAZ (24-20 cm) occurs at c. 9075 ^{14}C yr BP (10,220 cal yr BP) using sediment accumulation rates calculated in section 6.8.

This fire phase has been tentatively correlated to NAQ Phase 3, which according to sediment accumulation rates (Section 5.6), is estimated to have occurred at c. 8700 ^{14}C yr BP (c. 9650 cal yr BP). Correlation is based on the shape of the *Betula*, *Corylus avellana* and *Dryopteris filix-mas* curves. In both profiles *Corylus* pollen is reduced, followed by expansions in Cyperaceae, herbs and ferns. The *Corylus avellana* pollen concentrations decline in both profiles and if this is not solely a factor of preservation, it could be explained by the actual clearance of the shrub at the lake edges where most of the human activity was concentrated.

Poaceae pollen levels are relatively consistent at both sites suggesting that the reeds were not adversely affected by burning. However, microscopic charcoal assigned to species of *Juncus* occurs during Phase 3 at NAQ along with *Neurospora* fungi at the very end of the Phase, indicating that most of the human impact was probably along the lake edges once again. *Juncus* pollen is not preserved in the pollen record (Andrew 1984) and so burning of stands of this plant would go unnoticed in the pollen diagram except for the deposition of charcoal particles. This localised and *in situ* deposition of charcoal particles would then account for the much higher charcoal peaks at NAZ. Fewer macro charcoal pieces were deposited at NAQ because in addition to the spatial drop off of larger charcoal sizes, charcoal from *Juncus* is fragile (Dark 1998) and unlikely to travel far without breaking.

Phase 3 at NAQ may also equate to the first phase of burning at NM (Phase 1, c. 110 cm) on the south side of the island. Both sites are at the same stages of the hydrosere at this time, and show evidence for a decline in hazel, a short peak in birch, along with burning of reedswamp or the deposition of rush charcoal. The start of this phase of human activity has been dated to 8610 ±60 ^{14}C yr BP at NM (c. 9547 cal yr BP or 8730-8490 ^{14}C yr BP to 95% confidence limits), which is slightly later than the estimated date of approximately 8700 ^{14}C yr BP for Phase 3 at NAQ (c. 9650 cal yr BP). However, the dating framework at NAQ is purely an estimate so correlation of the two phases is entirely plausible.

7.1.3.4 Between 8900-8450 ^{14}C yr BP, (c. 10,030-9486 cal yr BP)

The final charcoal peak at NAZ (Peak 4, 13 cm) occurs at c. 8890 ^{14}C yr BP (c. 10,030 cal yr BP; using sediment accumulation rates) and is correlated with the very beginning of NAQ Phase 4 at c. 148 cm (c. 8600 ^{14}C yr BP; c. 9545 cal yr BP). At both sites *Corylus avellana* pollen and concentration levels start to peak and Cyperaceae levels are low. Charcoal concentrations and numbers of macro charcoal particles at NAZ are much lower than during the preceding phase, indicating that the main activity was yet to come or that it was much less intense. Acospores of *Gelasinospora* and *Sordariaceous* fungi at NAZ denote the very close proximity of dead and carbonised wood and humans or animals. The high percentages of Pteropsida (monolete) undiff. at NAZ (65% TLP) and the lower values at NAQ (45% TLP, including *Thelypteris palustris*), demonstrate the different stages of the hydrosere at different distances from the lake edge as well as the different levels of pollen preservation.

If the preceding correlations were correct, Phase 4 at NAQ would then equate to the large charcoal peak occurring around 92 cm at NM. This fire event has been dated to approximately 8450 ^{14}C yr BP (c. 9486 cal yr BP) by interpolation between the two radiocarbon dates reported in Section 4.6, whereas Phase 4 at NAQ is estimated to have occurred at approximately 8600 ^{14}C yr BP (c. 9545 cal yr BP). It is clear from the relative number and size of the charcoal fragments, that burning occurred much nearer to NM than NAQ during Phases 3 and 4 or perhaps at and/or between both localities. Vegetation disturbance and/or management are also discernible at both sites suggesting that there were two areas of contemporary human activity and/or vegetation disturbance.

The above correlations could call into question some of the radiocarbon estimates calculated for the three profiles. However, considering the low numbers of radiocarbon dates that have been obtained from the three sites, their standard errors, the presence of radiocarbon plateaux, and the low sample resolution at NAZ, the correlations are considered acceptable within the accuracy of the present data.

7.2 Spatial Deposition of Microscopic Charcoal Particles

Trying to determine the spatial deposition of charcoal from charcoal concentration and particle counts may seem fruitless given the large number of unknown variables, e.g. the spatial extent of the fire, the quantity and type of material burnt, the frequency and duration of each fire, the temperature of the fire and wind direction. In order to confidently correlate between profiles one would clearly need dated and defined concentrations of archaeological finds to relate to each charcoal phase at each site, as well as the ability to ascertain the spatial distance between the prehistoric fires.

Despite the present limitations of charcoal studies, the early Mesolithic data from No Name Hill appear to display some general trends. From these trends it is possible to propose some approximate threshold levels which, although perhaps not transferable outside of the region, may prove useful when locating potential areas for excavation or when interpreting future pollen and charcoal diagrams. The following table of concentrations and ratios (Table 7.2) provides a guideline, although there are bound to be exceptions, and any results will be subject to alteration in the light of future results:

Table 7.2 Definition of a charcoal peak and its spatial relationship to early Mesolithic fires

Charcoal Concentrations	
Concentrations $x10^{-5}$ cm^2 cm^{-3} (during Zones 5 and 6)	**Probable Source Area of Charcoal**
<150	regional and background fires within the catchment
100-300	Within a couple of hundred meters
>300-600	within 80-100 m of the sampling site and probably within 30 m
>750-1800+	within a few meters to 30 m of the sampling site

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Charcoal :pollen Ratio	
Ratio x10^{-9} cm^2 grain^{-1}	**Probable Source Area of Charcoal**
<25	regional and background fires within the catchment
25-30	within a couple of hundred meters
30-40	within 80-100 m and possibly within 30 m of the sampling site
40-150+	within a few meters, up to 30 m of the sampling site

From these results, the deposition of charcoal appears to drop off very sharply (almost exponentially), as is in accordance with the results of Rhodes (1996) and Moore (1999), although wind direction and eddie currents will no doubt be the decisive factors affecting the direction and deposition of any aerially transported charcoal particles.

7.3 Vegetation History at No Name Hill

The vegetation history to the north of No Name Hill is very similar to the vegetation history established for the south of the island in Chapter Four. The southern profile NM was located in slightly deeper water than NAQ and NAZ, consequently reedswamp and later sedge carr, appears to be more prolific along the northern island shore than along the southern shore. These differences are due to the different sub-water topography at opposite sides of the island and consequently the different rates of the local hydrosere development. There is no convincing evidence to support any significant changes in water level prior to zone NM-7b at No Name Hill (approximately 8200 ^{14}C yr BP).

The very gradual rise to high *Corylus avellana* values at NM is also a factor of the water depth. Waterborne inputs of *Corylus avellana* pollen would have reached the sampling site at NM from the very earliest point of hazel establishment on the island or even the surrounding catchment whereas, the reedswamp surrounding NAQ would have restricted inputs of hazel pollen until the shrub/tree was actually

established very nearby. Similar processes are likely to explain the lower juniper and willow pollen at NAQ. The only other differences between the northern and southern sites are the very local effects of vegetation disturbance caused by human activity.

7.4 Conclusions on Human Impact at No Name Hill

Occupation of the island began in the early Mesolithic just before c. 10,740 cal yr BP shown by Phase 1 fire activity at NAQ, although humans may have utilised the island from an even earlier date. Remains of wild horse (Rowley-Conwy 1999; Rowley-Conwy submitted) and the occurrence of Pre-Phase 1 charcoal peaks at NAQ suggest that humans used the island during the Pre-Boreal or even earlier.

The charcoal and pollen records analysed over the last four chapters infer that during the early Mesolithic, vegetation disturbance consisted primarily of accidental and/or deliberate burning of the reedswamp in a limited zone at the margins of the island. The exploitation/removal of woody species e.g. trees and shrubs was fairly limited, with only superficial clearance or utilisation (or coppicing) for raw materials. This was probably due to the spacious and open nature of the birch woodland, which did not restrict movement/visibility and provided shelter. Disturbance of the ground flora and churning of the soil on the dry land at the lake-side was probably mainly accidental and a bi-product of the activity areas, although stands of fern were severely affected along the northern edge of the island.

Once stands of *Corylus avellana* began to become established at around 9000 ^{14}C yr BP, the degree of human impact becomes more noticeable. In zone-6, fires occurred at more than one locality at the same time or small-scale fires were replaced by larger scale fires, which register a charcoal signal within the sediments on both sides of the island. In addition to continued firing of the lake margins, growth of *Corylus avellana* was sometimes encouraged but most of the time hazel was partially removed or disadvantaged by the human activities at No Name Hill. Removal of hazel was apparently undertaken to provide an increase in understorey herbs and grasses.

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In all cases, the pollen diagrams may be displaying the effects of a cluster of disturbances occurring within a small area. Recurrent fire disturbance in different areas and on different successional vegetation communities would be expected to produce a composite and cumulative change to the pollen rain. Perhaps even producing contradictory pollen responses so that even relatively intense disturbance appears to have been low-key. After all there is no pollen evidence to support increased *Salix/Populus* pollen due to coppicing, during the early Mesolithic at NAZ or NAQ, despite the discovery of an early Mesolithic hand axe from NAZ. The only other hand axes to be found in the Vale have derived from the excavations at Star Carr and Flixton Island. However, these episodes of woodland management are likely to be so transient within the pollen record that recording of such an occurrence would have to be highly fortuitous.

7.5 Further Archaeological Issues

Why did these early people decide to visit or occupy this island in the middle of the lake? What made the north side more appealing than the south side? Was it the well-drained soils or the view? The slope of the island edge and access to open water? Or was it the vegetation and the preponderance of reeds? And why did people keep coming back to the island especially when the island must have been too restrictive to provide a comfortable base for long-term settlement?

Perhaps the island was used purely as a lookout point and the knapping or antler processing concentrations were merely the result of 'boredom alleviation' activities whilst the hunters or look-outs killed time. The whole of the lake would have been visible from different vantage points on the island so game or visitors and predators would be easily spotted. Lithic evidence from trenches BJ on the east of the island and NC along the south of the island, suggest *in situ* knapping of core material brought specifically to the site (Conneller 1998).

The island could have been used as a hunting and butchering place, where carcasses were taken whilst the meat was dried and smoked prior to transport. At trench BJ as well as showing *in situ* knapping activities, 57% of the flints are burnt

(Conneller 1998). Driving game into deep water makes hunting from boats and then transport of carcasses very easy (Utchiyama 1996). The northwestern tip of the island would have proved ideal for this purpose as it provided quick access to deep and open water. Flint remains from the northern lake edge show fairly low-density lithic use, but from a variety of different tasks, "...*perhaps based on the exploitation of a spatially discrete resource at the lake edge*" (Conneller 1998:52). The tools were generally brought to the site ready made and probably represent a number of lost or broken tools that accumulated over hundreds of years. The concentrations of blades and flakes at the very lake edges are similar to finds from Star Carr *"probably indicating widespread cutting activities"* (Conneller 1998:53), or butchering of carcasses.

Perhaps the reedswamp was fired purely to create animal browse? No Name Hill is a relatively remote location, and by firing areas well away from human settlements the Mesolithic people could create a temporary but ideal hunting location, especially if No Name Hill was on a well-utilised animal crossing point across the lake (in combination with Flixton Islands). Unfortunately, only 'absolutely' dated and detailed analysis of the lithic and faunal records, in association with interpretation of the environmental record, will provide the answers to these questions. Whatever the utilisation of the island, the charcoal record suggests repeated but (probably) short-term occupation of the island over decades at a time.

7.6 Chapter Seven - Summary

- At least six fire phases are observable at No Name Hill between c. 9700-6100 ^{14}C yr BP, with each phase consisting of a number of sub-phases.
- At least one additional fire phase occurred along the eastern or western edges of the island, but this has not been successfully identified in any of the profiles analysed so far.
- Each site was repeatedly occupied throughout the early and later Mesolithic, with each (intermittent) occupation lasting several decades.
- Any fires occurring along the northern edge of the island prior to 9000 ^{14}C yr BP are not visible at NM to the south of the island.

- Most charcoal particles (particularly those >8800 μm^2) appear to be deposited within a few tens of meters of the fire and probably within 30 m.

- It has been possible to tentatively define the magnitude of a 'local' charcoal peak and suggest threshold charcoal concentrations for the spatial identification of future sites.

- The low number of radiocarbon dates and the presence of a radiocarbon plateau poses a serious limitation to the establishment of an accurate chronology of human occupation and vegetation change.

Chapter 8 - Flixton School Field

8.0 Introduction to Flixton School Field - Location and Geology

The early Mesolithic site at Flixton School Field (TA 0485 8013), was first discovered in 1988 but not extensively field-walked until 1993, or even partially excavated until 1994. It is located on the southern edge of the Vale, due north of the former Primary School building in Flixton Village, on what would have been the southern lake edge of Palaeo-Lake Flixton (Figure 8.1). The site is positioned on an area of chalk strata covered by late-glacial cover-sands.

8.1 The Archaeological Excavations

8.1.1 Site Location

The site is north facing and lies approximately 1.9 km to the south east of Star Carr. To the west of the site, the dry land formed a small promontory that would have projected out into the lake during the early post-glacial. To the east of this headland, an isolated bay or inlet would have been created, possibly offering shelter from any strong westerly winds (see Figure 8.2).

Access to the lake would have been unconstrained in the very early post-glacial as the ground slopes off abruptly into an area of relatively deep water at the lake edge. *"The choice of location may also have been influenced by the presence of a freshwater stream running into Lake Flixton some 400 m to the east "*says Lane (1998:70), with another spring fed stream occurring approximately 200 m to the west. The settlement area would also have been ideally situated for the exploitation of freshwater fish, as the promontory created an area of still water in the lee of the headland, which would have provided an ideal spot to place a fish trap (P. Rowley-Conwy *pers. com*).

Just a few hundred metres to the south of Flixton School was the base of the Wolds, with its easy access to the uplands and potential grazing lands for large mammals. According to Bush and Flenley (1988) and Bush (1988, 1993), polleniferous

sediments from Willow Garth, show that the Wolds sustained permanent areas of grassland throughout the Holocene. If this last statement is true, then Lake Flixton may have provided a permanent watering hole for herds of grazing mammals, due to the paucity of permanent watering holes on the permeable chalk uplands. However, Bush's work has been criticised by a number of authors e.g. Day (1996a), and research from the southern chalk uplands by Waller and Hamilton (2000), suggests that grassland would have only survived on the steepest, most unstable slopes.

8.1.2 Site Excavation

The full extent of the early Mesolithic site at Flixton School was not realised until 1997. Since then excavations have shown that it extended over 90 m along the lake edge, covering an area of least 1500 m^2. The eastern limit of the site still needs to be determined, but overall, Flixton School Field has produced the widest scatter of flints so far in the Vale, indicating a potentially large settlement. Most finds were concentrated along the eastern side of the promontory (Figure 8.2) with the main flint concentrations, near an area of relatively deep water. So far over 1029 pieces of struck flint and 93 pieces of bone have been recovered from early Mesolithic contexts (1998 figures). Abundant later Mesolithic flints have also been found on the higher ground to the south along with a relatively thick charcoal layer stratigraphically linked to the later Mesolithic.

8.1.3 Bone

The bone assemblage is predominated by wild cattle (aurochs*)* but also includes red deer antler, dog and several horse teeth. This is in contrast to the red deer dominated assemblages found elsewhere in the Vale. The low species diversity of the recovered bone could reflect an economically, narrowly focused site. This in turn would suggest that the site was only occupied at specific times of the year. However, the relatively low number of bones that have been recovered, combined with their poor preservation, means that analysis and interpretation of the finds is restricted. Further excavations are needed before it is possible to elicit economic insights from the bones, that are statistically valid.

Nevertheless, two things can be deduced with some certainty. Firstly, the remains of wild horse *(Equus equus)* places at least some of the occupation at Flixton

School within the initial stages of the post-glacial. This occupation is likely to have occurred prior to 9790±180 ^{14}C yr, as this is the youngest radiocarbon date to have been obtained from the remains of a wild horse in Britain. (Clutton-Brock and Burleigh 1991). Secondly, the remains of one (or possibly two) dogs have been found at Flixton School, conceivably suggesting domestication or at least semi-domestication of this animal, perhaps as an aide to hunting (Rowley-Conwy 1999).

8.1.4 Flint

The majority of the lithic finds were found in trenches OI and OH along the shoreline of the ancient lake (see Figure 8.2.) OI was microlith dominated although there was also a variety of other tools present. Slightly to the east on higher ground was trench OH, which was scraper dominated. Just a few metres to the west of the main concentrations of flint scatters, in trench PB, lay an isolated cache of twelve partially modified nodules of raw till flint, carefully stacked in a small pile. Because of their magnitude, the nodules *"...are likely to have been especially selected for their size"* (Conneller 1998:55). Conneller also states that, *" It would also have taken a certain amount of investment of time to collect a range of nodules of this size and the fact that a range of stages and techniques of working are present may suggest that they have been accumulated from a variety of contexts, possibly over a period of time... ....Interestingly, most of these nodules are of very poor quality, possibly too poor even for knapping. It thus seems that the significant thing about this cache is not so much its quality as a secondary raw material source in the landscape, but more the simple presence of these large nodules - the very fact of their deposition creating a relationship between people and a place"* (Conneller 1998:55).

8.1.5 Adjacent Sites

Traces of flints, indicative of low impact early Mesolithic activity have also been detected 150-200 m to the west of Flixton School, at Flixton School House Farm (Figure 8.2). So far only traces of low impact activity have been recovered, although a partial *Bos primigenius* skeleton and an early Mesolithic charcoal layer have also been identified. The skeleton still awaits analysis and dating, but pollen evidence suggests that the wild ox died in the early stages of the post-glacial (Cummins 2000b). Most of the lithic finds were concentrated along the top of a

headland or promontory, which itself formed the western side of another isolated inlet. No occupation appears to have occurred in the intervening area between this second site and Flixton School.

8.2 Palaeoecological Research at Flixton School

In order to investigate the vegetation that surrounded the early Mesolithic site at Flixton School, a pollen profile (FS) was taken less than 30 m from the early Mesolithic lake edge and just north of trench OI (Figure 8.2). Due to the fact that the present-day soil has been severely damaged by ploughing, a series of pollen preservation tests were carried out prior to sampling. Trench FS was then excavated in an area that would provide well preserved sediments, spanning the whole of the early Mesolithic, but as near to the ancient shoreline as possible.

8.3 Sampling

The sediment profile was retrieved during the August 1995 archaeological field-season. Samples were retrieved from an open 2x2 m trench using a series of four 0.5 m overlapping monoliths tins. The top of each tin was levelled and then the tins were cut from the cleaned north facing section of the trench, wrapped in polythene, labelled and stored until analysis was possible.

8.4 Lithostratigraphy

The broad lithology consists of organic lake muds overlying unconsolidated silts, which have been deposited on top of grey coarse sand containing large gravel pieces and chalk fragments. Only the lowest 0.85 m of sediment has been analysed, due to poor pollen preservation in the upper sediments. All measurements were taken from a datum of 25.63 m OD.

Depth (in cm)	Description
249-285	Dark brown organic mud with extensive reed macrofossils and vegetative remains

285-299	Dark brown organic mud with fewer reed macrofossils and vegetative remains
299-303	Light brown to grey silty-sand
303-308	Brown organic silt
308-310	Light brown to grey sandy-silt
310-312	Unconsolidated grey silty-sand
312-335	Grey coarse sand with mixed assemblage of gravels, pebbles and chalk fragments

8.5 Pollen, Charcoal and Microscopic Fungal Analysis

Sub-samples of 0.5 cm^3 were taken for pollen, charcoal and microscopic fungal analysis at intervals of 1-2 cm. Following the analysis of the preliminary results, contiguous samples of 0.1-0.2 cm^3 were taken every 1-2 mm across selected horizons. Samples were prepared for analysis following standard procedures (Chapter Two and Appendix 1).

8.6 Radiocarbon Dating

Six samples were submitted for small sample (Accelerator Mass Spectroscopy) radiocarbon dating. The results are presented in Table 8.1 below:

Table 8.1   **Radiocarbon Dates from Profile FS**

Depth (in cm)	Lab Code	Radiocarbon yr BP	$\delta^{13}C$ (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
262-4	Beta-104481	9020±60	-28.4	10,208; 10,197; 10,193; (10,355-9921)	Reed peat
265-7	Beta-104480	9030±60	-27.1	10,211; (10,357-9922)	Reed peat

Depth (in cm)	Lab Code	Radiocarbon yr BP	$\delta^{13}C$ (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
268.1-269.2	Beta-94434	9220±100	-29.2	10,398; 10,335; 10,334; 10,316 10,312; 10,297; 10,290; (10,673-10,193)	Reed peat
282.6-283.7	Beta-94433	9900±100	-33.2	11,254; 11,253; 11,234; (11,899-11,165)	Organic sediment
297.7-299	Beta-94432	10,230±100	-29.7	11,945; 11,790; 11,779; (12,730-11,357)	Organic sediment
303-304.8	Beta-94431	11,430±100	-27.1	13,427 (13,809-13,050)	Organic sediment

8.7 Zoning the Diagram

The pollen diagram was zoned using CONISS and dated using the radiocarbon dates (above). The results are appended onto the pollen diagram in Figure 8.3. The zones have been compared to the regional profile D and then labelled accordingly to broadly correlate with it and the rest of the profiles from the study.

8.8 The Palaeoecological Sequence – Profile FS

The pollen diagram (Figures 8.3-8.7). has been divided into three local pollen assemblage zones (prefixed FS) which are listed below:

8.8.1 Early Mesolithic c. 9700-9000 ^{14}C yr BP

LPAZ FS-5   310-269.5 cm *Betula-Dryopteris filix-mas*

FS-5a 310-299 cm   *Betula*-Poaceae-Pteropsida (monolete) undiff

FS-5b 299-281.5 cm   *Betula-Dryopteris filix-mas.*

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FS-5c 281.5–269.5 cm   *Betula-Corylus avellana*-Cyperaceae

LPAZ FS-6 269.5-263 cm *Corylus avellana-Betula*-Cyperaceae.

8.8.2 Early to Later Mesolithic c. 9000-<8800 ^{14}C yr BP

LPAZ FS-7 263-252 cm *Corylus avellana*-Pteropsida (monolete) undiff. -
Thelypteris palustris.

The pollen zones are described in Table 8.2.

8.9 Interpretation of the Radiocarbon Dates

The bottom three dates in Table 8.1 (Beta-94431-94433) were measured to elucidate the timing of critical horizons within the bottom half of the sediment core. Even though the organic content of the samples was low, it was hoped that extended counting during the AMS measurements would provide valid age estimates. Unfortunately, all three dates look 'too old' when compared with other radiocarbon dates that mark similar vegetation changes, within the region. Housley (1998:30) concludes that he is,... *"seeing an older bias due to the mixing of the atmospheric and DIC synthesised vegetative matter."* That is, the samples contain a mixture of lake and terrestrial vegetative matter and so have been affected by a hard-water error to some degree.

Samples Beta-104480-81 and Beta-94434 were measured in order to date the second phase of fire activity (Phase 2- Figure 8.7). The samples were composed of reed peat, and so were unlikely to be affected by any hard-water errors. Housley (1998:30) states that, *"The upper three radiocarbon measurements are probably valid age estimates"* and *"statistically there is no significant difference between the three determinations..."* (X2-Test: df=2 T=3.2 [5% 6.0]).

8.10 Sediment Accumulation Rates

In order to ascertain the average rate of sediment accumulation across the entire profile, it is necessary to supplement the top three radiocarbon dates from FS with

other radiocarbon dates obtained by Day and Mellars (1994), see Table 8.3. (below):

Table 8.3   **The approximate age of early Mesolithic sediments in profile FS (see also Figure 8.8)**

Approx Depth in cm in FS	^{14}C yr BP Age Estimate	Approx Cal yr BP (2σ, 95%)	Lab Code/ Source (Dark 1998)	Dated Horizon
263	9020±60	10,208; 10,197; 10,193; (10,355-9921)	Beta-104481	end of Zone FS-7
266	9030±60	10,211; (10,357-9922)	Beta-104480	end of FS Phase 2
268.5	9220±100	10,398; 10,335; 10,334; 10,316 10,312; 10,297; 10,290; (10,673-10,193)	Beta-94434	start of FS Phase 2
287	9385±115	10,430 (11,090-10,242)	OxA-4376	arrival of *Corylus* at the lake edge at Star Carr
303	9500±70	10,715 (mid-point) (11,114-10,560)	OxA-3350	the early Holocene increase of *Dryopteris filix-mas* at Star Carr

Calculations yield an average (approximate) rate of sediment formation of 0.083 cm yr^{-1} during the early Mesolithic. Naturally, the rate of sediment deposition would have varied quite considerably about this average level as shown in Figure 8.8. The pollen concentration curve (Figure 8.9) can also be used as a proxy indicator of accumulation rates. This demonstrates that during some pollen zones

the accumulation rate was quite slow, e.g. the middle-top of zone FS-5b, and at other times the rate was quite high during the first half of FS-5c.

A crucial factor in this thesis, is the rate of sediment formation during periods of fine-resolution pollen analyses. Extrapolation between the top three radiocarbon dates at FS suggest that during FS Phase 2, the peat sequence was deposited at an average rate of 0.0283 cm yr^{-1} (using the mid-points). The resolution of each pollen sample in Phase 2, is therefore between 3.5 yr (for a 1 mm sample) and 7 years (for a 2 mm sample). This is in comparison to the accumulation time of 4 yr cm^{-1} from the fine resolution samples from the regional profile. However, interpretation of the pollen concentration curve (Figure 8.9) shows that although accumulation varied considerably during Phase 2, accumulation rates were never above average. Therefore, an interval of 3.5 years per mm is probably a fairly accurate estimation of the sample resolution during Phase 2. The 1 mm samples are therefore adequately comparable with the samples from the regional profile.

During Phase 1, the pollen concentration curve also fluctuates significantly with concentration levels either average or above average. Therefore the sample resolution during Phase 1 must be somewhat lower than during Phase 2, perhaps 3.5-5 years for every 1 mm sample. Once again this is adequately comparable to the fine resolution samples from the regional profile.

8.11 Pollen Preservation
Analysis of the percentage of indeterminable pollen grains (Figure 8.10) can provide insights into the depositional and post-depositional processes that have affected the microfossils (Moore *et al* 1991).

8.11.1 Zones FS-5a and 5b   c. 310 – 284 cm
Unidentifiable pollen grains generally form less than 10% TLP, demonstrating that pollen preservation is excellent.

8.11.2 Zone FS-5c and FS-6   c. 282 – 266 cm

This period signifies a slight change in the preservation status of the sediments. Unidentifiable pollen grains now reach up to 20% of the TLP, predominantly due to an increase in the contribution of crumpled and corroded grains. This shift is attributed to slightly elevated erosion and a shift towards drier (more terrestrial) conditions.

8.11.3 Zones FS-6 and FS-7   c. 266 – 252 cm

Above 267 cm, there is a sudden and rapid growth in the number of unidentifiable pollen grains. Corroded grains dominate the assemblage and this is attributed to progressive oxidation and desiccation of the sediments, following the effects of modern day drainage practices. According to Traverse (1994) palynologists should be concerned when the percentage of indeterminable pollen types increases rapidly to c. 50%, indicating a loss of pollen by deterioration. Fragile pollen grains e.g. *Ulmus,* are therefore likely to be under-represented in the pollen sum as they will have been preferentially corroded.

8.12 The Charcoal Record

The charcoal record (Figures 8.6 and 8.7), shows the constant deposition of background charcoal, typically concentrations of about 150×10^{-5} cm^2 cm^{-3} or less. This is equivalent to the deposition of background regional charcoal, as observed in the regional profile (Chapter Three). This charcoal rain is mainly composed of particles less than 400 μm^2 in area, with a small proportion of particles extending up to 1760 μm^2.

From the diagram it is possible to identify 3-4 periods of more intense charcoal deposition, depending on the method of data presentation. Charcoal as a % TLP depends on the total pollen deposition, which is a factor of pollen productivity and sediment accumulation. Conversely charcoal concentrations provide a more standardised measurement of fire activity. Only large peaks in the charcoal profile should be taken as catchment fires, due to background levels (Swain 1973; Clark 1988a). Chapter Seven has tentatively identified the threshold levels of charcoal, required to indicate localised human activity, (i.e. > c. 300×10^{-5} cm^2 cm^{-3}). Using

these threshold levels there appear to be at least three periods of human activity within 80-100 m of the sampling site, and possibly as near as 30 m.

All charcoal peaks appear to represent continued burning over a long period, which is inconsistent with the deposition of charcoal caused by natural fires. The return period between the fires is also less than one would expect for the British Isles. Chandler *et al* (1983) quote a return period of 6000 years for a natural fire 1 ha in size. Close inspection of two of the fire events (Phase 1 and Phase 2, Figure 8.7), using fine resolution sampling (1-2 mm intervals), reveals that the charcoal diagram has a very saw-toothed profile. This indicates that fires occurred within fairly quick succession, a phenomenon unlikely to be attributable to successive lightning strikes in the same area. The macro charcoal curve also shows a good relationship with the charcoal : pollen ratio, indicating that the charcoal is likely to be derived from local rather than regional fire sources.

8.13 Microscopic Fungi and Episodes of Burning

Identifying the origin of microscopic charcoal to plant species is very problematic, due to the lack of diagnostic features present within the small charred particles. However, very occasionally, diagnostic cell structures are visible within large charcoal fragments enabling the origin of the charcoal to be identified. At the very top of the pollen profile, a piece of rush (*Juncus*) charcoal has been identified at a depth of 252 cm. This probably corresponds to a local fire at the start of the later Mesolithic. Further down the profile, during charcoal Phase 2, one piece of wood charcoal and one piece of microscopic rush charcoal have been identified at a depth of 268.4-268.5 cm. Lastly, towards the bottom of the pollen diagram, charcoal from reed (*Phragmites*), was found at 301 cm and 300.1-2 cm, during charcoal Phase 1. Occurrence of these charcoal particles within the stratigraphy are shown in Figures 8.6 and 8.7.

During Phase 1 the sampling site was located within marginal open water, comprising sandy pool deposits, in a developing mosaic of hummock and pool vegetation. This is demonstrated by the presence of *Zygnema* type algae (Figure 8.7) which occurs within pools of water at the transition to terrestrial conditions.

Various other algal spores are present which also occur in aquatic, sandy pool environments, e.g. Type 225, 228, 229, (van Geel *et al* 1989). Hummock vegetation is shown by the presence of fungi of *Geoglossum sphagnophilum*, Type 10 and Type 203 (van Geel *et al* 1989).

By the start of charcoal Phase 2, conditions at the sampling site were almost terrestrial, shown by the high incidence of the fungal spore *Geoglossum sphagnophilum*. A single acospore of *Neurospora* (Type 55c, van Geel 1986), signals the incidence of a local bog fire at a depth of 267.2 cm. Simmons and Innes (1996b) observe that at North Gill, on the North York Moors, *Neurospora* peaks show a good relationship to macro and microscopic charcoal peaks, and should therefore be a good indicator of local fires. The unidentified aquatic fungal spore (X), increases at the same time as a period of higher accumulation rates and periods of lower charcoal input. This fungal spore may therefore be associated with vegetation that colonises fresh sediment.

8.14 Synthesis and Human Impact Test 1 – Conventional Interpretation of Profile FS (Figures 8.3-8.7 & 8.11-8.12)

In Profile FS sedimentation starts some time after the beginning of the post-glacial and continues until the start of the Later Mesolithic c. 8800 ^{14}C yr BP. The profile has been radiocarbon dated but the low organic content of the lower samples; the chalk substrata and the hard water catchment mean that the oldest dates are mostly anomalous.

The profile has been interpreted using a combination of pollen and charcoal percentage and concentration data. Interpretation of the vegetation changes is heavily reliant on the pollen percentage data, as it is better at displaying the spatial changes in the vegetation compared with the pollen concentration data, which is affected by accumulation rates (Jackson 1994:259).

8.14.1 Early Mesolithic <c. 10,000-8800 ^{14}C yr BP

Vegetation change throughout the profile follows the same broad pattern as the regional profile (D) and the vegetation at No Name Hill. At the start of Zone FS-5

birch woodland with willow and juniper is already well established. Correlation with other radiocarbon dated sites suggests this occurred sometime after 10,000 ^{14}C yr BP (e.g. 10,120±180 ^{14}C yr BP at Roos Bog, Holderness, Beckett 1981; 10,275±175 ^{14}C yr BP at AK87, Vale of Pickering, Simmons *et al* submitted). Aspen (*Populus*) co-existed with birch at the lake edges although *Populus* pollen concentrations are very low in comparison with Day's (1996a) profile. This could either be a reflection of the actual population levels along the southern edge of the Vale or attributable to poor preservation and susceptibility to oxidation in the shallow lake-edge deposits.

Pollen frequencies fluctuate considerably especially during periods with fine resolution sampling but many of the larger fluctuations seem to be attributable to changes in regional pollen production (by comparison with Profile D, Chapter Three).

8.14.1.1 Phase 1 >c. 10,000-<c. 9400 ^{14}C yr BP

Not all fluctuations are caused by natural changes in pollen output however, and a period of high charcoal deposition in zone FS-5a (Phase 1, Figure 8.7) is likely to be due to the activities of hunter-gatherers. There appear to be saw-toothed fluctuations in the birch, willow, fern and grass curves with a noticeable increase in woodland and lake-edge species diversity. Charcoal deposition is also very variable although any links with the vegetation are tenuous.

The fires are estimated to have occurred over a period of c. 160-225 years (from 303.5-299 cm, using calculations in Section 8.10), although occupation may have been intermittent or may have varied greatly in intensity over that time. (Whether or not fluctuations in charcoal concentrations can be taken to reflect fluctuations in fire intensity is currently unknown, especially given such small sample resolutions). Charcoal concentrations also imply a period of fire activity before Phase 1, perhaps denoting an even earlier phase of human occupation. Unfortunately these periods of occupation are undated as the radiocarbon date from the top of Phase 1 (Beta-94432), has almost certainly been affected by the hard water error and must be ignored.

The effect on the vegetation of these periods of occupation seems to have been very subtle. At Flixton School very little change to the woodland occurred although there does appear to be a very small increase in woodland shrub pollen possibly denoting small and ephemeral canopy openings (see Figure 8.11). Some soil disturbance may have occurred at the woodland edge, allowing an expansion in grasses and almost certainly providing areas for the expansion of *Dryopteris filix-mas*. Following this proposed phase of human activity, charcoal levels are depleted slightly although they are still sometimes greater than background levels, suggesting that fire activity may have continued in the nearby catchment.

8.14.1.2 c. 9400-9220±100 ^{14}C yr BP

By approximately 9400 ^{14}C yr BP (mid-zone 5b; c. 10,430 cal yr BP), the regional expansion of *Corylus avellana* occurs and the ground flora starts to become less diverse as the woodland canopy begins to close. Zone FS-5c sees the extension of sedge-beds as Cyperaceae progressively expands further out into the lake. At 285 cm there is a large drop in tree/shrub pollen concentrations due to this *in situ* change to sedge swamp. The low pollen concentrations are likely to be caused by a rapid accumulation of sediment and the increased contribution of pollen from aquatic and lake-edge communities, e.g. Cyperaceae. Consequently the *Betula* pollen curve decreases although actual populations of *Betula* are unlikely to have changed considerably.

Even though *Betula* populations remain stable, the marked drop in *Betula* pollen percentages may be attributable to increased contribution by *Pinus* and then *Filipendula*. As usual it is hard to ascertain the real change in *Pinus* from the pollen data. In zone FS-5c *Pinus* concentrations are still no higher than they were in zone FS-5a or b, when *Pinus* was not regarded as an important part of the local vegetation. However, the increased rate of sedimentation inferred from the total pollen concentrations, would dilute the pollen concentration and it is possible that *Pinus* grew briefly on areas of the drier chalk strata. Alternatively the pollen peak could be associated with the deposition of floating grains in a tidemark at the lake-edge.

By 280 cm the water level has dropped to below 25 cm as it is now too shallow to support *Nymphaea alba* populations at the sampling site. The peak in *Filipendula* (probably) *ulmaria* at 276 cm appears to be real and due to suitable habitats created by the transition from wetland to dry land as it replaces the emergent aquatic *Equisetum*. *Filipendula ulmaria* is intolerant of permanently waterlogged sites so its pollen is derived from plants growing on the dry land edge where nutrient stress or shade from the tree canopy restricts other species. However, the peak in *Filipendula* is short-lived as competition from other species increases and the environment changes from unshaded to shaded mire. The large variation in Cyperaceae pollen production is probably caused by very local spatial changes in pollen output and pollen dispersion from *in situ* plants.

8.14.1.3 Phase 2 c. 9220±100-9030±60 ^{14}C yr BP

During Zone FS-6 a second phase of fine resolution pollen analysis is undertaken during another period of enhanced charcoal deposition. Associated changes to the vegetation imply possible manipulation of the woodland and lake-edge vegetation by hunter-gatherers. Variations in birch and hazel woodland create areas for the brief expansion of woodland shrubs and herbs, and cause peaks in *Corylus avellana* pollen production, as more pollen is able to flower and reach the lake deposits.

The vast variations in Cyperaceae are probably explicable by very local variations and over-representation of *in situ* sedge pollen. Total pollen concentrations do decline suggesting a rapid increase in sedimentation, conceivably providing the right environment for the sedges to flourish. The reed swamp, which is by now *in situ,* would produce a swamping of Cyperaceae pollen diluting the contribution of all other species. Alternatively it could be due to a period of fluctuating water levels although there are no other species to strongly support this. Finally it may also (in part), be attributable to the actions of hunter-gatherers, as there appears to be a relationship between charcoal and Cyperaceae levels (see Figure 8.12 and Figure 8.16). This time the occupation phase covers a period of c. 105 years (see section 8.12) and is dated to between c. 9220 ±100 ^{14}C yr BP and 9030 ±60 ^{14}C yr BP (c. 10,326-10,211 cal yr BP).

8.14.1.4 c. 9030±60-8800 ^{14}C yr BP

Towards the top of the profile, small stands of *Pinus* may have developed on the drier soils and *Betula* and *Salix* have now been almost excluded and probably exist only as lake-edge remnants. The lake edge has receded beyond the sampling point and the high levels of marsh fern and a reduction in Cyperaceae suggest a drying of the environment at the conversion to dry land.

Phase 3 > c. 9020±60<c. 8800 ^{14}C yr BP

Between c. 263-258 cm there is another phase of human related fire activity near FS, occurring just after c. 9020±60 ^{14}C yr BP (c. 10,200 cal yr BP). Peaks in charcoal concentrations and the Charcoal:pollen ratio coincide with a large decline in *Corylus* pollen and a peak in Cyperaceae. Peaks in marsh fern and macro charcoal particles and a decline in Cyperaceae pollen follow this at c. 260 cm. Small quantities of fire resistant, *Pteridium* and *Potentilla* also occur during this phase.

The low species diversity and generally low pollen concentrations for all species except ferns makes it hard to ascertain the reasons for these pollen changes, however it seems likely that hazel populations did decline and that Cyperaceae pollen briefly increased. This could be either due to a decline in hazel stands allowing a greater influx of sedge pollen onto the sampling site, or due to an increase in sedge populations directly related to the firing of areas of reedswamp.

By 8800 ^{14}C yr BP (the approximate date for the top of the profile), *Ulmus* and low levels of *Quercus* would be expected to have become established within the vicinity of the sampling site. Some pollen grains have been observed from both species, but the very low concentrations suggest a preservation bias in the data, as the peat has become oxidised post-deposition and preservation levels have dropped (see Figure 8.10). The charcoal curve shows the start of what may be another phase of human activity (Phase 4) and the presence of *Juncus* charcoal at 252 cm. However, the low pollen preservation levels and low species diversity preclude any meaningful analysis of this phase.

8.14.2 Interpretation of the Fine Resolution Phases 1 and 2

Both sections of fine resolution sampling (Phase 1 and 2) will be looked at individually, as they appear to have been affected by different environmental processes. Interpretation is made difficult because many of the pollen curves fluctuate considerably, due to natural successional changes. Sampling at a high resolution also increases the amount of information obtainable, so that pollen diversity appears to increase although in actual fact the species diversity may not have changed (see Section 3.10.2, Chapter Three). The additional information provided by charcoal particle analysis is therefore used to determine the effects (if any) of human activity. The charcoal could be derived either from burning of vegetation or from domestic fires, although Clark and Royall (1995) suggest that domestic fires would be unlikely to produce a significant peak in the charcoal record.

8.14.2.1 Phase 1 ≤c. 9700> c. 9400 ^{14}C yr BP

This first phase of fine resolution sampling (Phase 1: 303.5-299 cm, Figure 8.11) occurs just after the rise of *Dryopteris filix-mas*, which is believed to be a region-wide expansion. By correlation with pollen diagrams and dates from Star Carr (Figure 8.13), this period of fire activity and human settlement may have occurred just before or contemporaneous with occupation at Star Carr i.e. occurring at approximately c. 9700-9650 ^{14}C yr BP (c. 11,000-10,920 cal yr BP). Accelerator dates from the Flixton School profile suggest a much older date, probably due to the low carbon content of the sediments.

Charcoal deposition during Phase 1 cannot be explained merely as an erosional effect, as the saw-tooth pollen and charcoal curves imply no mixing of the sediments. Neither can the charcoal be explained as 'a reflection' of the activity at Star Carr, because Day's (1996a) profile, which was taken only 400 m away from the occupation site at Star Carr, shows only a limited trace of human activity reflected in the charcoal or pollen records. (FS is nearly 2 km away). The entire phase appears to be composed of several periods of intense burning followed by periods of less intense fire activity. If charcoal concentrations are taken as a reliable

indicator of occupation intensity, then this suggests several minor phases of occupation.

What then was the effect of the fire activity and what purpose would it have served? Charcoal deposition coincides with slight changes to the tree, shrub, herb and fern curves, which suggests the creation of small openings at the woodland edge although there is only a minimal expansion of herbs and grasses. Unfortunately, there is no clear pattern to the changes in the pollen diagrams. Sometimes *Dryopteris filix-mas* increases when *Betula* decreases and sometimes the fluctuations are synchronous (see Figure 8.15). The key is probably what actually happened to *Betula* and the effect of the fire if any, on the tree stands. If there was an actual opening up of woodland then this may have led to prolific flowering (or sporation) of the understorey, e.g. ferns. Sometimes the fluctuations in *Betula* are opposite to the fluctuations in the charcoal curve i.e. declining with increased fire activity, but sometimes they are not. Declines are by no means large and very transitory as in subsequent years *Betula* pollen regains or even exceeds its previous levels. This can be interpreted as tree re-establishment or increased pollen deposition into the canopy clearing. Delayed reaction to the opening of the canopy and ground cover produces an increase in pollen from *Populus, Salix* and light-demanding shrubs, e.g. *Sorbus/Crataegus*. This is caused either by some limited small-scale seedling expansion or elevated pollen influx into open areas. Thus, disturbance may have infringed slightly upon the woodland edge causing scrub and woodland edge species to flower successfully and *Populus* seedlings to become established after a short time lag (see Figures 8.14a-b for pollen concentration values).

Pteropsida (monolete) undiff. and *Dryopteris filix-mas* (the woodland understorey ferns) show a slight negative response to charcoal deposition, but the effect is very subtle. *Dryopteris filix-mas* declines with the fire peaks but then increases afterwards (Figure 8.15), either increasing numbers of spores reach the open areas or new establishment is possible in the newly created areas. On the whole, the *Dryopteris filix-mas* curve does appear to be inflated relative to the regional profile D (see Chapter Three), suggesting soil disturbance and the creation of areas of bare soil suitable for its expansion. Soil erosion is suggested by the presence of spores of *Zygnema* type algae. However, if there was an actual opening up of woodland

then this may have led to prolific flowering of the understorey instead of an actual increase in fern numbers, as male ferns do not produce spores until 6-7 years old. Any reduction in fern spores may then be the result of trampling by humans and not necessarily the destruction of fern stands. This reduction in ferns at a time of woodland opening is similar to patterns observed at Loch an T'Sil, South Uist (Cummins 1994; Edwards 1999) and on Shetland at Dallican Water (Bennett *et al* 1992) and Loch of Brunatwatt (Edwards and Moss 1993). At Dallican it is taken to indicate possible grazing by deer but could also be caused by trampling under foot.

In addition to trampling of stands of male fern there appears to have been a small increase in species associated with disturbed ground or nitrogen rich soils, either within the already fairly open woodland or at the lake edge. Percentages for *Artemisia, Rumex acetosa, Plantago media* and *Urtica dioica*, all exceed the levels observed in the natural vegetation (see Chapter Three). Quantifying how significant these levels are though, remains problematic as these species may just be related to the soils and climate of the early post-glacial environment.

The charcoal curve shows little relation to the vegetation changes (see also Chapters Four to Six), suggesting a mosaic of vegetation changes, complex taphonomic processes or a mainly domestic origin for the charcoal. However, two pieces of microscopic charcoal have been identified as belonging to reed species (*Phragmites*), which suggests at least some burning of the vegetation at the lake edge. Despite this evidence there is no other proof for direct burning of the flora, as no large numbers of fire resistant taxa are observable, e.g. *Chamerion angustifolium, Pteridium aquilinum, Thelypteris palustris, Potentilla* or *Melampyrum pratense*. Pollen grains characteristic of settlement areas are present, e.g. *Plantago major*, Chenopodiaceae, *Artemisia* type, *Urtica dioica*, but may also be related to the soils and climate of the early post-glacial environment.

Utilisation of the particular area lasts 160-225 years (i.e. using accumulation rates in Section 8.10 over a depth of 45 mm). Within this period of settlement, three or four minor-phases of occupation occur, lasting about 30-50 years each. Inputs of inorganic particles also increase during this phase, possibly associated with

increased runoff over the land or the destabilising effect of humans or animals trampling on the soil.

Finally, the pollen changes during Phase 1 are very subtle but this may be what one should expect from small-scale manipulation of vegetation that occurred about 30 m (if not more) away from the sampling site. Around *Saami* settlements *"It was observed that the percentage of grass and herb pollen types drops markedly with increasing distance from the settlement or pen "* (Aronsson 1994:41). But even if the fire activity took place more than 30 m away from the sampling site, it probably did not occur more than 200 m away, as suggested by charcoal concentrations from No Name Hill. (A period of charcoal activity in the north, profile NAQ, is not visible in the southern profile NM, 200 m away). Table 7.2 Chapter Seven, if directly applicable, also suggests that the occupation at Flixton School took place within 80-100 m of the sampling site.

8.14.2.2 Phase 2 c. 9220±100-9030±60 ^{14}C yr BP

Approximately 400 years later at c. 9200±100 ^{14}C yr BP the same area was once again used by Mesolithic peoples (Phase 2). This phase has been radiocarbon dated to c. 9200-9000 ^{14}C yr BP (Beta-94434, Beta-104480-81; c.10,326-10,211 cal yr BP). The first date is slightly older than expected, but considering the large standard error for each measurement, the dates are accepted.

Within this second Phase of occupation (267-270 cm), the vegetation changes are completely different from those that took place during Phase 1. By now the lake edge has receded as the lake starts to fill in and the vegetation at the lake edges is starting to encroach into the lake. The sediments suggest that reed-swamp was infringing into the shallow open water and that at the shoreline a band of marsh fen would have occurred. Occupation of the site appears to have been in a number of intermittent episodes, with at least three or four minor phases in all (Figure 8.12). Occupation occurs over approximately 60-105 years and seems to have a relatively clearly defined fire regime.

This time the fire activity seems to have concentrated on the woodland and lake edge or mire communities. The pollen diagram (Figure 8.12) shows significant changes to the woodland composition with large variations in birch and hazel pollen at the lake edge. Most notable is the saw-tooth fluctuations in the Cyperaceae record, the reduction to almost negligible amounts of grass pollen and the slight reduction in total fern populations. The main species that appear to be involved in any burning are Cyperaceae and Poaceae, e.g. *Phragmites, Glyceria, Cladium*, fen sedges and shore edge grasses, and there is also microscopic charcoal evidence for the burning of rush (*Juncus*). There appears to be a causal link between the sedge and charcoal curves as well as a reduction in *Phragmites* (Poaceae) pollen as Poaceae stands are apparently superseded by Cyperaceae. The result is the saw tooth curve with increased flowering and pollen succeeding the fire episodes (see Figure 8.16). Unfortunately the pollen concentration values (Figure 8.14a-b) are of limited use in the interpretation of the diagrams, as they appear to be responding primarily to changes in accumulation rates. They do suggest that most pollen types are drowned out by the local sedge pollen inputs.

Lake-side taxa are continually low and meadow taxa practically non-existent during the fire episodes. The presence of microscopic charcoal from rush, wood and the occurrence of *Neurospora* fungi support the theory of vegetation burning. Unfortunately *Juncus* pollen never survives in a fossilised form, and its contribution to the vegetation and the extent of burning of rush stands remains unknown. However it is likely to have formed a significant part of the vegetation and probably accounted for a high proportion of the burnt vegetation, if the regular occurrence of microscopic *Juncus* charcoal found at Star Carr and in Chapters Four to Six, this volume, is accepted as proof of its existence.

On dry land the already low values of *Dryopteris filix-mas* decline further (Figure 8.5), possibly indicating disturbance of the woodland understorey at the woodland edges. A closer examination of the tree/shrub pollen data reveals no consistent pattern to the vegetation changes. Sometimes there is a slight decline in tree pollen coincident with charcoal peaks and sometimes there is an increase. Despite this overall lack of pattern, there is some evidence for disturbance of the woodland, with increases in light demanding trees and shrubs such as *Populus* and *Salix*, and

the appearance of woodland edge species such as *Sorbus* type, *Sambucus* type, *Sanguisorba* and *Eunoymus* (although this may be a factor of sample resolution).

At the start of Phase 2, *Betula* pollen increases significantly which is perhaps a flowering response to the openings created by what looks like a disturbance to the *Corylus* woodland. Later on, towards the top of Phase 2, *Corylus* pollen values become inflated, possibly because more of its pollen is able to reach the ground or because the shrub itself is able to expand into areas once used by *Betula*. These changes presumably occur as a result of clearance, which indicates that in addition to burning of the reedswamp, some areas of woodland were also affected.

8.15 FS Human Impact Test 2 – 95% Confidence Limits

From Section 8.14 (above) the main species identified as being affected by human activities were:

Phase 1- *Dryopteris filix-mas, Betula*, Pteropsida, *Populus, Salix*, light-demanding shrubs, e.g. *Sorbus/Crataegus* and herbs associated with disturbance.

Phase 2 – *Corylus, Betula*, Pteropsida, Cyperaceae, Poaceae and woodland edge trees and shrubs.

Phase 3 - *Corylus*, Cyperaceae, *Thelypteris palustris* (Marsh fern) and possibly *Pteridium* and *Potentilla* in small quantities.

This section tests whether these changes are larger than the expected variations in the pollen percentage counts. Figures 8.17-8.19 show the 0.95 confidence intervals for all pollen and spore data. Figure 8.17 is plotted for the whole of the profile, whereas Figures 8.18 and 8.19 are plotted for the fine resolution fire Phases 1 and 2 only.

In Figure 8.17 *Betula, Corylus*, Poaceae, Cyperaceae, *Dryopteris filix-mas, Thelypteris palustris*, Pteropsida (monolete) undiff., *Filipendula, Myriophyllum verticillatum, Equisetum* and *Nymphaea* all show pollen fluctuations that exceed the 0.95 confidence intervals. The remaining species are either persistently within the 0.95 confidence intervals or have values that are too low to enable meaningful statistical analyses.

During Fire Phase 1 (Figure 5.18), *Betula, Salix*, Poaceae, Cyperaceae, *Nymphaea* and ferns exceed the 95% confidence limits at any time. Whilst in Phase 2 (Figure 5.19), *Betula, Corylus*, Poaceae, Cyperaceae *Thelypteris palustris*, Pteropsida (monolete) undiff exceed the confidence intervals. The fluctuations of the remaining species in each diagram are once again either persistently within the confidence intervals or their values are too small and preclude analyses.

The results are presented in Table 8.4 below:

Table 8.4 Significant changes in pollen and spores during the early Mesolithic compared with charcoal deposition

Species	Peak	Decline	Charcoal Pattern /Reason
Betula	304		**Pre-Phase 1** Peak (all types)
	302.5		**Phase 1** Peak (all types)
		292.5-288	Macro charcoal peak in FS-5b
	287-280		Small peaks but not > background levels
		273-273	Macro charcoal peak in FS-5c
	Fine resolution 270-269.65 268	**Fine resolution** 268.15-268.05	**Phase 2** not > background levels Charcoal not > background Peak-(all charcoal types)
		266-260	Competition with *Corylus*
Salix	**Fine resolution**	**Fine resolution** 299.75	**Phase 1** Peak in charcoal conc. and ch:pollen (no macro pieces)
Corylus	**Fine resolution** 270-267		**Phase 2** No discernible pattern apart from constant deposition of background charcoal
	266-264		Recovery from Phase 2
		262-260	**Phase 3**
	252		Recovery from Phase 3
Poaceae		304	**Pre-Phase 1** Peak (all types, including macro)
		302.5	**Phase 1** Peak (all types)

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Species	Peak	Decline	Charcoal Pattern /Reason
	Fine resolution 267.3	Fine resolution 269.05	Phase 2 Just before charcoal peak Charcoal peak (all types)
Cyperaceae		302.5	Phase 1 Peak (all types)
		288	None
Cyperaceae	282-274		Small peaks but not > background levels
	272		Just after small macro peak in FS-5c
	Fine resolution 269	Fine resolution 268	Phase 2 Charcoal Peak (all types) Charcoal peaks (all types)
	Fine resolution 270-267		Phase 2 No discernible pattern apart from constant deposition of background charcoal
		267-263	Small peaks but not > background levels
	262		Phase 3 charcoal conc peak
		260	Phase 3 macro peak
Dryopteris flix-mas	Fine resolution 302	Fine resolution 301.9	Phase 1 Peak in Charcoal:pollen Significant peak in Pteropsida with macro charcoal peak
	297-291		Preservation bias - due to fluctuations in Pteropsida
Thelypteris palustris		277	Natural?
		275	Natural?
	Fine resolution 269 268 267	Fine resolution 269.5	Phase 2 Taphonomic due to a rise in Pteropsida Significant decline in ferns with charcoal peak-(all types) Charcoal peak (all types) Taphonomic due to a decline in Pteropsida

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Species	Peak	Decline	Charcoal Pattern /Reason
	260		Natural/hydrosere/taphonomic bias but also **Phase 3**-macro peak
Pteropsida	**Fine resolution** 302.5-301.4 301.9-301.55		**Phase 1** Taphonomic due to peaks and declines in Dryopteris Peaks still significant with: macro charcoal at 301.9 cm charcoal peak 301.55 cm (no macros)
	297-291		Taphonomic due to Peak or declines in *Dryopteris filix-mas*
		279	None
	273-274		Small macro peak in FS-5c
	Fine resolution 269.5-268.5 269.05 268.3	**Fine resolution** 269.0 (significant even with Thelpteris)	**Phase 2** Taphonomic due to decline in Thelypteris Prior to charcoal peak Charcoal peak (all types) Small peak in char:pollen
	261-252		Natural/hydrosere/taphonomic bias but also **Phase 3** macro peak
Filipendula	277.5-274.5		Natural/hydrosere
Myriophyllum verticillatum	267.5-285.5		Natural/hydrosere
Equisetum	284-277		Natural/hydrosere
Nymphaea	**Fine resolution** 301.7 301.3	**Fine resolution** 301.55 299.95	**Phase 1-Natural?** Ch peak -After macro peak Still ch peak Ch peak all incl macro Ch peak -After macro peak
	282.5-280		Natural/hydrosere

8.15.1 Results of Human Impact Test 2

By considering the 0.95 confidence intervals of the data it has been possible to identify only the significant changes in the pollen curves that may be associated with human impact, although defining the peak or decline in the data is somewhat problematic. The impact of hunter-gatherers appears to be much less intense than hypothesised in Section 8.14. The small amounts of pollen from herbs and woodland-edge shrubs, which are usually taken to indicate human disturbance, have not been included in the analysis. This is because their pollen values are too low to allow statistical analysis. The results can be summarised as:

8.15.1.1 Pre-Phase 1

Prior to Phase 1 there is one episode of human impact on the vegetation. At 304 cm, birch briefly peaks and grass briefly declines, seemingly in response to a peak in charcoal deposition, identifiable in all charcoal curves.

8.15.1.2 Phase 1

Four phases of human impact occur although the most significant vegetation changes occur in the first half of Phase 1 between 302.5 and 301.5 cm. At 302.5 cm birch briefly peaks, while grass and sedges decline, at the same time as a peak in all the charcoal curves, possibly indicating burning of the reedswamp. Slightly later (c. 302-301.5 cm), ferns (*Dryopteris filix-mas* and Pteropsida) peak with the deposition of charcoal, suggesting disturbance on the dry land. The changes in *Nymphaea* probably reflect over-representation of pollen from *in situ* plants, and the pollen fluctuations are probably not a response to changes in charcoal deposition.

Around c. 301-300 cm, when no significant vegetation changes are observable, human groups may have burnt small areas of reedswamp shown by the deposition of microscopic reed charcoal. Then finally, towards the end of Phase 1 at 299.75 cm, willow declines at the same time as a peak in the charcoal concentrations and Charcoal:pollen ratio, although no macro pieces >8800 μm^2 were deposited. Throughout the latter half of Phase 1, the presence of small quantities of *Zygnema* spores suggest soil erosion.

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8.15.1.3 299-270 cm

During this part of the profile no local charcoal peaks have been defined, despite the occurrence of small numbers of macro charcoal. This is because charcoal concentration levels are always lower than background levels. Despite this fact there are many significant fluctuations in pollen and spores. The main changes are to birch and sedge. Small birch declines occur along with the deposition of small quantities of macro charcoal, whilst sedge fluctuations are thought to be due to local over-representation of *in situ* plants. Any birch fluctuations are probably caused by background environmental factors (BV) or may be the result of human activities in the wider catchment (although this seems unlikely).

Thelypteris palustris, Filipendula, Myriophyllum verticillatum, Equisetum and *Nymphaea* all seem to be responding to local changes in the hydrosere and do not appear to be related to charcoal deposition. Fluctuations in *Dryopteris filix-mas* seem to be caused by a taphonomic bias, as numbers of Pteropsida (monolete) undiff. increase when *Dryopteris* levels drop. This occurs when the male fern spores loose their distinctive outer coating and can no longer be assigned to species.

8.15.1.4 Phase 2

There are three discernible episodes of human impact. At 269 cm Cyperaceae peaks and ferns decline. At 268 cm both birch and marsh fern peak, whilst sedges decline. Finally at 267.3 grass pollen peaks. All pollen changes occur during peaks in the charcoal curve (shown on all charcoal curves). These findings may indicate small scale burning of the reedswamp. This is supported by the presence of wood and rush charcoal and one occurrence of *Neurospora* fungi at 267.2 cm.

It can be seen that the decline in Poaceae at 269.05 cm actually occurs before there is any significant peak in charcoal. Furthermore, most changes in *Corylus avellana, Betula* and Cyperaceae, seem to be entirely unrelated to charcoal deposition. These changes may therefore be the result of some simple form of resource utilisation in combination with background environmental factors (BV).

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Fluctuations in Cyperaceae may be caused by inputs of erosion from activity areas, which create suitable areas for its expansion (see Hicks 1993).

8.15.1.5 Phase 3 and after

Corylus declines at the same time as the deposition of Phase 3 charcoal, suggesting some clearance of the scrub. Cyperaceae continues to fluctuate probably due to local deposition and over-representation of its pollen, although at least two changes appear to be coincident with charcoal peaks. Ferns (mainly *Thelypteris palustris*) also peak but may be mainly associated with the progression of the hydrosere.

8.16 FS Human Impact Test 3 – Background Variations and 95% Confidence Limits

The results from Section 8.15 suggest that human activities had a marginal (but statistically significant) impact on the vegetation communities at Flixton School. Nonetheless, these changes to the vegetation do not take into account the background variations in pollen output (BV) caused by natural environmental factors. Chapter Three has already established that the background variations in pollen production are fairly high, depending on the time window of analysis. In this section, the changes to the vegetation that are attributed to human impact in Section 8.15, will be tested to see if they are greater than background variations in pollen production. The test is only applicable to the part of zone FS-5 of the early Mesolithic that correlates with zone D-5 of the regional profile (see Chapter Three).

Figures 8.20a-f show the pollen percentage curves for *Betula,* Poaceae, Cyperaceae, *Salix, Dryopteris filix-mas,* Pteropsida (monolete) undiff. during zone FS-5 of the early Mesolithic (no other species fall within this time period). A 'best fit' regression line has been plotted to show the mean trend in the vegetation throughout the zone i.e. the approximate trend in the vegetation before human impacts. The mean value for the 0.95 confidence interval (IV) has been plotted either side, along with the expected background variability (BV). If the pollen or spore fluctuations exceed the combined BV+IV limits, it would seem probable that real changes to vegetation are occurring. If these changes are also accompanied by

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charcoal peaks (see Tables 8.4 and 8.6), then these changes can be confidently attributed to human activities.

The percentage BV value applied to the diagrams is calculated using the method outlined in Chapters Three-Five. Calculations are shown in Table 8.5 (below).

Table 8.5   IV and BV % calculations for various taxa from Profile FS.

Profile	Species	FS % IV	D3 % BV	FS % Range	D3 % Range	BV Scaling Factor	FS % BV	E% = $\sqrt{(IV^2+BV^2)}$
Zone FS-5	*Betula*	3.82	9	77-39	78-37	1.00	9	9.77
	Poaceae	2.15	4.2	3-18	4-22	0.82	3.44	3.99
	Cyperaceae	1.83	1.7	2.4-8.3	0.3-7	1.00	1.7	2.5
	Dryopteris filix-mas	1.9	4.2	0-13	0-9	1.00	4.2	3.6
	Pteropsida (monolete) undiff.	2.34	5.28	2.4-29	0-11.3	1.00	5.28	5.77
Fine Resol'n Phase 1	*Salix*	1.58	2.1	3-7.5	2.4-6.6	1.00	2.1	2.63
	Dryopteris filix-mas	2.2	3.2	0.12-13	0-8	1.00	3.2	3.88
	Pteropsida (monolete) undiff.	2.43	3.56	9-29	2-10.5	1.00	3.56	4.3

8.16.1 Early Mesolithic Results.

The BV+IV model appears to work quite well although there are a few inexplicable peaks or declines in the data that lie outside the BV+IV limits. However it is noticeable that a linear regression curve is not always the 'best fit' regression line and that polynomial curves would sometimes be more applicable e.g. *Dryopteris filix-mas*. The choice of curve would of course depend on the best-fit regression of the data in the regional profile. Unfortunately polynomial

regression was not undertaken in this thesis as the software was not available, but it would be recommended for any future use of this model.

The results of the BV+IV analysis are presented in Table 8.6 below:

Table 8.6 Changes in Pollen and Spores in excess of BV+IV limits, during the early Mesolithic zone FS-5 ≥284 cm.

Species	Peak	Decline	Charcoal Pattern /Reason	Human Impact Y/N
Betula	304		**Pre-Phase 1** Peak (all types)	Y
	302.5		**Phase 1** Peak (all types)	Y
		287&285	Small charcoal peaks but not > background levels	? -could be from Flixton SH Farm
Salix	**Fine resolution** Peak at 299.85 and then decline at 299.75		**Phase 1** Decline in charcoal then peak in charcoal conc and ch:pollen ratio..	Y – decline in charcoal allows *Salix* to flower before burning resumes
Poaceae		304 & 302.5	**Pre-Phase 1** Peak (all types, including macro) **Phase 1** Peak (all types)	Y- Model breaks down but shows peaks at 304.5 and 303.5 instead
Cyperaceae		302.5	**Phase 1** Peak (all types)	Y
		288	None > background	N-Anomolous
Dryopteris flix-mas	**Fine resoln** 302	**Fine resoln** 301.9	**Phase 1** Peak in Charcoal:pollen Significant peak in Pteropsida with macro charcoal peak	Y Y
Pteropsida		**Fine resoln** 302 & 301.9	macro charcoal at 301.9 cm and charcoal peak 301.55 cm (no macros)	Y
Cyperaceae-Anomolies		304.5		N-Not significant pollen change
	290-289			N-Not significant pollen change

Species	Peak	Decline	Charcoal Pattern /Reason	Human Impact Y/N
Dryopteris Anomolies	292.3		Preservation bias	N- change in Preservation
		310-302.5	*Dryopteris* values much lower than rest of curve	N – linear curve not applicable
Pteropsida Anomolies		301.3	Preservation bias	N- change in Preservation

These results confirm the results obtained in Section 8.15 (Test 2- 95% confidence limits). Prior to 284 cm there are five phases of vegetation change that can be confidently attributed to human activities. These are:

Pre-Phase 1: 304 cm Birch peaks and grass decline potentially caused by disturbance of the groundflora or reedswamp, which allows birch pollen inputs to increase at the sampling point.

Phase –1:   302.5 cm Birch peaks and grasses and sedges decline, probably due to the same processes that occur in Pre-Phase 1

302-301.9 cm *Dryopteris* peaks first of all and then declines, caused by disturbance to the undergrowth at the woodland edge.

301 and 300.2 reed charcoal is present reflecting *in situ* burning of the reedswamp.

299.85-299.75 cm willow peaks and then declines. An increase in willow pollen probably caused by decreased inputs from other species.

All phases of human impact that occur after FS Phase 1, and are listed in Section 8.15.1.4 and 8.15.1.5 are assumed to be real. In reality, the impact on the vegetation during fire Phases 2 and 3 may have been less intense than it appears, as background variations in pollen output have not been taken into account.

8.17 Conclusions on Human Settlement at Flixton School

It looks as if the human activity that took place during Phase 2 resulted in a more complex form of vegetation manipulation than that which occurred during Phase 1.

In Phase 2 both the lake edge vegetation and the woodland become modified to some degree. The exact pattern of changes and processes involved are however unknown, although comparison of the charcoal and pollen curves suggests there is a link (Figure 8.16). During Phase 1 the vegetation disturbance was predominantly limited to the reedswamp and understorey of ferns. (Shrub and herb diversity may also have increased during both Phases but this could not be tested statistically).

8.17.1 Repetition

The frequent occurrence of charcoal peaks in the early Mesolithic at Flixton School suggests repeated occupation of the same or nearby sites (see Figures 8.6 and 8.7). Charcoal particle size and concentration diagrams suggest a local origin for the fires, although the settlement foci probably shifted through time to other areas within the catchment. The two phases of early Mesolithic settlement investigated, caused no long-term effect to the vegetation, but only short-term changes to the woodland or to the lake-edge succession.

8.17.2 Timing and Nature of Fire Phases

No consistent patterns can be observed within the vegetation changes but some overall trends and correlations are visible. This is due to the fact that each sample is composed of more than a single year of pollen accumulation. Significantly, humans do not appear to be taking advantage of any natural breaks in tree cover, as suggested by many authors e.g. Brown (1997). Or if they are, then this does not appear to be the sole factor driving the location of human activity, as tree cover is still largely continuous and there is no pattern to the observed changes in vegetation.

During FS-5a, early Mesolithic charcoal appears to coincide with increased flowering or growth of *Betula*. During Phase 1 (and pre-Phase 1), the woodland edges were disturbed and the undergrowth and ground were trampled during a term of periodic settlement. The presence of microscopic charcoal also indicates that at least some deliberate or accidental burning of the reed beds also occurred. No radiocarbon dates are available to date this phase of occupation, but it is believed to have occurred at or before 9650 ^{14}C yr BP ($\geq$c. 10,900 cal yr). Faunal remains of

Equus equus, which is generally regarded as a tundra/steppe species, supports this early Holocene date and suggest that occupation (probably Pre-Phase 1) took place sometime before or around 9790±180 ^{14}C yr BP (see Clutton-Brock and Burleigh 1991).

At about 9200-9000 ^{14}C yr BP (c. 10,326-10,211 cal yr BP), during Zone FS-6, manipulation of the lake edge and woodland vegetation occurred. Fairly similar changes also occurred at Star Carr (e.g. Mellars and Dark 1998), although in that particular case reed (*Phragmites*) and willow (*Salix*) were the principal species involved. This may indicate that the lake edge fires at both sites were caused by accidental spread of fires from hearths or that the vegetation changes were caused for the same economic reasons. This should not be surprising as the ethnographic literature indicates that the deliberate and systematic burning of vegetation was an extremely widespread practice amongst recent hunter and food gathering communities.

The exact reasons for the vegetation disturbances are unknown although some hypotheses will be put forward in Chapter Ten. Analysis of the faunal and artefact record may shed light on these actual activities and enable rejection or acceptance of various hypotheses.

Two other Fire phases occurred just after c. 9020±60 ^{14}C yr BP (c. 10,200 cal yr BP) and just after c. 8800 ^{14}C yr BP. During Phase 3 areas of hazel woodland appear to have been cleared but the nature of any vegetation change in Phase 4 is hard to ascertain.

8.17.3 Duration

If it is accepted that the stratigraphic spread of microscopic charcoal accurately reflects the duration of a fire event, then it is possible to estimate the duration of occupation. (The flaws in this argument are examined by Bradbury (1996) and Whitlock and Millspaugh (1996) in their papers). Consequently, Phase 1 lasted 160-225 years (or up to 285 years including Pre-Phase 1). This combined fire Phase comprised five different periods of occupation each lasting approximately

30-50 years in total, although there may have been periods of abandonment within or between each minor phase of occupation.

Phase 2 in contrast lasted approximately 60-105 years and contained three periods of occupation, each lasting around 15-40 years (approximately).

8.18 Comparison of FS with the natural vegetation, Profile D.

The vegetation history at Flixton School is similar to Profile D, although FS includes a higher pollen representation from local and lake-edge vegetation, due to its lake edge sampling location. In particular, the *Dryopteris filix-mas* curve appears to be slightly attenuated in places at FS in comparison to its regional spore deposition curve (Figure 3.4b) at approximately the same time. *Dryopteris filix-mas* also persisted for much longer within the environment at Flixton School.

Populus pollen is actually observable at Flixton School, which is in contrast to most of the other lake-edge profiles analysed in this thesis. This is rather surprising considering the acidity of the lake-side sediments, but is quite likely to be a factor of the close sampling intervals.

The immigration of *Corylus avellana* appears to be very gradual at FS when compared with the sudden regional rise in *Corylus* pollen. This is more than likely to be attributable to the different rates of sediment accumulation between the two profiles and thus sample resolution. Sediment accumulation is much higher at the lake edges than in the centre of the lake and therefore vegetation changes appear to occur over a wider stratigraphic span at the lake edges. Only extensive radiocarbon dating of sediments from differing parts of the Vale will reveal the true synchronicity of this vegetation event. However, initial results from Star Carr do suggest that the immigration and establishment of hazel was fairly synchronous within the small spatial area of the Vale (Dark 1998).

In terms of the charcoal record, the early Mesolithic charcoal peaks at Flixton School broadly correspond to small peaks in the charcoal record from Profile D (see Figure 3.5). In contrast, the seemingly large impact of later Mesolithic peoples

at Flixton School around 8900-8800 ^{14}C yr BP is not observable in the Charcoal:pollen ratio from profile D, although peaks are visible in the charcoal concentration diagram.

8.19 Comparison of FS with Star Carr

The vegetation changes that occurred during the two periods of early Mesolithic occupation at Flixton School were subtle in comparison to the very sharp changes in birch, grass and fern pollen curves that occurred at Star Carr. At Flixton School there were no big declines in grass although slight fluctuations in Poaceae pollen did occur quite frequently. The subtle vegetation changes at FS during Phase 1 can be explained by the remoter position of the sampling core in relation to the dry land. This also accounts for the lower contributions of *Salix* and higher contributions from *Betula*. At Star Carr the vegetation around the sampling site appears to be more open due to over-representation of *in situ* reed-swamp pollen. Further comparisons of the two sites will be undertaken in Chapter Ten.

8.20 Comparison of FS with the Rest of the Vale

The vegetation trends at FS are similar to the broad vegetation changes seen in the other profiles examined within this thesis. The fine resolution pollen changes seen at Flixton School (profile FS) are also similar to the fine resolution vegetation changes that occurred at NAQ i.e. during the early Mesolithic there appear to be saw-tooth fluctuations in the birch, willow, fern, grass and sedge curves with a noticeable increase in woodland and lake edge species diversity. Later, once hazel starts to become established around the lake, it is also affected by human activities.

8.21 Wider Issues

There is no convincing evidence for substantial lake level changes in the early Mesolithic at Flixton School as proposed by Cloutman (1988a). Basin-wide analyses of water level changes will be undertaken in Chapter Eleven along with analysis of any links between the *Corylus* rise and the presence of charcoal.

- Flixton School was potentially a large settlement which left a spread of lithic and faunal remains spanning >90 m of the lake shore.

- At least some transient human occupation must have occurred at Flixton School before 9790±180 ^{14}C yr BP (c. 11,196 cal yr BP), due to the presence of wild horse remains.

- Four periods of human induced fire activity have been identified (pre-Phase 1 and Phases 1-3.

- Pre-Phase 1 probably occurred before c. 9700 ^{14}C yr BP (c. 11,000 cal yr BP) and lasted anything up to about 50-60 years. Disturbance of the woodland and understorey was very subtle.

- Phase 1 started c. 9700-9650 ^{14}C yr BP (c. 11,000-10,900 cal yr BP) and lasted for around 160-225 ^{14}C years. It consisted of four minor phases of occupation. Reedswamp was burnt, understorey ferns were disturbed and there may have been minor openings in the birch woodland allowing shrubs to flower or become established. Ground disturbance and soil erosion also occurred.

- Phase 2 occurred between 9220±100 and 9030±60 ^{14}C yr BP (c. 10,326-10,211 cal yr BP). Occupation lasted for a total of c. 60-105 ^{14}C yr and occurred in three separate minor-phases. Once gain the reedswamp was burnt (including stands of rush), and changes to the birch and hazel woodland are also likely to have occurred. Cyperaceae appears to have benefited from any human occupation or human related fires.

- Phase 3 occurred just after 9020±60 ^{14}C yr BP (c. 10,200 cal yr BP) and lasted for c. 200 ^{14}C yr BP (using this large sample resolution). There was some clearance of hazel woodland and sedges flourished either as a result of burning or because there was an increase in erosion from human activities.

- The beginning of a fourth phase of fire occurrence is observable at the top of profile FS c. 8800 ^{14}C yr BP. Little information is available but rush charcoal has been identified at 252 cm.

- Evidence for vegetation fires are supported by charcoal layers in Later Mesolithic sediments from Flixton School and early Mesolithic sediments from Flixton School House Farm c. 150 m to the west.

- Small amounts of charcoal from Flixton School House Farm may have travelled as far as Flixton School, especially in the time-span between FS Phases 1 and 2.

- Pollen preservation has deteriorated in sediments younger than c. 9000 ^{14}C yr BP. This shows that drainage is threatening the recovery of palaeoecological information pertaining to the early Mesolithic.

Chapter Nine - Barry's Island.

9.0 Introduction - Location and geology

The site called Barry's Island (TA 0613 8042) was formerly a large island (approximately 1700 m^2), located at the southeastern end of Lake Flixton during the early Mesolithic (Figure 9.1). The island appears to have been close to the deep (pre-Holocene) palaeo-channel of the River Derwent, which would have retained open water for much of the Mesolithic and perhaps even into the Neolithic and later (Cloutman 1988a). Over the course of the Holocene, the island was gradually submerged beneath several meters of peat growth. However, since the start of the twentieth century, land drainage and subsequent peat deterioration and shrinkage, has meant that the island has re-emerged as a low hill on land belonging to Mr Barry Kitchen of Folkton.

9.1 The Archaeological Excavations

The archaeological excavations took place every August from 1992 through until 1996. Determining the exact position of the archaeological site at Barry's Island proved to be problematic, due to a complex depositional history and the construction of farm buildings. It soon became clear that a trapped sand lens (context 9113), occurring in the north of the island, overlaid and truncated the underlying peat and glacial deposits (contexts 9116, 9117, 9118). The sand layer itself was rich in faunal and lithic remains but much of the lithic material displayed a characteristic sheen with rounded edges, suggesting post-depositional movement in a fluvial environment. During post-excavation analysis both the lithic and faunal assemblages were determined to be of a mixed date, containing artefacts from the early and later Mesolithic periods, and in the case of the faunal assemblage, bones dating to the final Palaeolithic. Consequently, it was deduced that the sand layer had been deposited by a high-energy stream that had reworked a number of older deposits, not necessarily from the island itself. Finds dating to the Bronze Age and Neolithic have also been found but no Upper Palaeolithic tool forms or flakes have been recovered from any trench or test pit at Barry's Island.

9.1.1 Flint

In total, 1255 flints have been collected from the island (Lane 1998), with much of the lithic material recovered from the uppermost contexts, namely the sand layer. Due to the complexity of the deposits, few *in situ* artefacts were recovered from the island. Altogether, three *in situ* early Mesolithic flint scatters were identified. Small and discrete flint scatters were excavated from trenches LAO and LYY, near the northern edge of the island (just to the south of LAP), where the land rapidly drops away into deep water (Figure 9.2). The third fairly localised and *in situ* flint scatter was located along the south-western side of the island at LG.

Detailed analysis of the flint assemblages can sometimes provide information about the actual activities that took place at the sites. For example, the flints from context 9117 in trench LAO, produced a very unique assemblage which *"appears to have involved the decortification and additional roughing out of about sixteen nodules into preforms and cores.....Presumably the missing preforms and cores would have been removed by their manufacturer(s) to be further worked when the need arose"* (Conneller 1998:61). Meanwhile at LYY (contexts 9117/9119), an episode of flint knapping occurred on what would have been the lower shoreline, in amongst reed-beds of *Phragmites*.

9.1.2 Bone

So far, 591 bones have been recovered from the various deposits at Barry's Island, including 279 bones that were sealed within the sand layer (Rowley-Conwy 1999). In its entirety the assemblage contains remains of red deer (*Cervus elaphus*), aurochs (*Bos primigenius*), roe deer (*Capreolus capreolus*), wild horse (*Equus ferus*), elk (*Alces alces*) and wild pig (*Sus scrofa*). The assemblage consists of a high proportion of red deer and large numbers of splintered bones, which show signs of spiral fracturing to extract marrow (Rowley-Conwy 1995; Utchiyama 1996).

A selection of the faunal remains contained within the trapped sand horizon have been dated, revealing a wide chronological width, spanning the final Upper Palaeolithic to the end of the Mesolithic, e.g. $10,160\pm90$ ^{14}C yr BP from a horse premolar (OxA-9330) and 5730 ± 60 ^{14}C yr BP (OxA-8045) from the remains of elk.

However, some of the bones are definitely derived from an area of early Mesolithic settlement as the remains of an aurochs have been dated to 9690±60 ^{14}C yr BP (OxA-8100).

When considered as a whole, the faunal assemblage from Barry's Island is large enough to allow the implementation of statistical analysis and palaeoeconomic interpretations of the site function. Such analyses have been undertaken by Rowley Conwy (1995) and Utchiyama (1996), despite the possibility that most of the bones have been derived from secondary sources. Rowley Conwy (1995) tentatively suggested that Barry's Island was utilised as a regular base camp, specialising in exploitation of red deer and bone marrow extraction. Utchiyama (1996:57) on the other hand, regards the site as being too specialised to be used as a base camp and instead suggests that *"....it is worth considering the possibility that the site was used as a secondary distributing centre for transporting meat to a place at a distance"*. Regardless of their different interpretations about the function of the site, both researchers agree that the faunal remains (excluding remains from the sand layer) suggest that at least one period of human activity took place during the autumn or winter. This is based on an elk jaw from an animal killed in the period January to March and two aurochs teeth tentatively assigned to a kill undertaken in the late summer/autumn (Rowley-Conwy 1999:11; Utchiyama 1996:50).

9.2 Palaeoecolgical Research

Two sediment profiles, LAL and LAP (Figure 9.2) have been analysed from the island, in order to investigate the vegetational and environmental impact of any archaeological settlement.

9.3 Sampling of Profile LAP

9.3.1 Location

Profile LAP was taken from the northern edge of the island where the land slopes off rapidly into deep water. The sediment profile was taken from near to trenches LAO and LYY (Figure 9.2), in order to investigate any early Mesolithic human impact on the vegetation and to investigate the formation of the sand layer in more

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detail. The sediments were formed in a shallow hollow, so they should provide insights into the local and extra-local vegetation upon the island during the early Holocene.

9.3.2 Sample Excavation

A sediment column was retrieved during the August 1995 archaeological field-season. Samples were retrieved from an open 2x2 m trench using a series of four 0.5 m overlapping monoliths. The top of each monolith tin was levelled relative to a datum of 25.27 m OD. The tins were then cut out of the cleaned south facing section of the trench and wrapped in polythene before being stored at <3°C until analysis was possible.

9.4 Lithostratigraphy of LAP

The broad lithology consists of glacial sands overlain by slightly organic sands, which were superseded by lake muds. The deposition of lake muds was briefly interrupted by a period of sand deposition, prior to overgrowth by peat. The detailed lithology is as follows (see Figure 9.5):

Depth (in cm)	Description
0-133	Unsampled black crumbly oxidised peat
133-167	Dark brown reed peat with sedge and vegetative remains
167-182	Orange and black, coarse, oxidised sand with peat incursions
182-235	Dark brown reed peat with sedge and reed vegetative remains
235-239	Orangey-brown *Sphagnum* peat including *Sphagnum* spore capsules
239-254	Dark brown lake detritus with vegetative remains
254-259	Dark grey organic silt
259-261	Light grey organic silt
261-269	Brown lake detritus
269-270	Greyey brown organic sand
270-272	Grey slightly organic sand

9.5 Metal Concentration and Particle Size Analysis from LAP

Samples of 1 cm^3 were taken for particle size analysis across the sand layer in LAP at the following depths: 168-169 cm, 170-171 cm, 173-174 cm, 175-176 cm, 177-178 cm, 179-180 cm. The samples were sieved to remove the any particles >2 mm before the remaining sample was passed through a Coulter Counter Machine which electronically analyses the size composition of the particles.

Selected samples of 1 cm^3 were also analysed for the total available concentrations of metals, Sodium (Na), Magnesium (Mg), Potassium (K), Calcium (Ca), Iron III (Fe3$^+$) and Manganese (Mn), according to the solution preparation method 1 of Bengtsson and Enell (1986). The results were interpreted in light of the research undertaken by Engstrom and Swain (1986) and Engstrom and Wright (1984).

9.6 Results of Metal Concentration and Particle Size Analysis

The results of the metal concentration analyses are presented in Figure 9.3. Erosional inputs peak between 175-176 cm, shown by the synchronous peaks in Sodium, Potassium and Magnesium. A peak in Manganese at 175-176 cm indicates that the sediments were laid down in waterlogged conditions as Manganese becomes preferentially mobile in reducing conditions (Engstrom and Swain 1986; Engstrom and Wright 1984).

The results of the particle size analyses are presented in Figure 9.4. The sand layer shows a slightly positively skewed, very selective, depositional event. The grain size distribution is bimodal, consisting mainly of medium to fine sand, with large flint and bone pieces (although these are not represented in the graph). The deposit is highly sorted and such selective transport occurs at very specific velocities and may suggest the sample is windblown or is a very well-sorted water event. Due to the large deposits of slightly polished flint and bone the latter scenario is more likely. Particle size data infers the stream current had a high competence, flowing with a bed load of pebbles, bones and flint in a supporting matrix of quartz. Cohesion in the sediment was low due to the low clay content, as the strong river current carried away the fine particles during high discharge events. Deposition of context 9113 probably occurred during a single event, or several very similar events, because the

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grain size profiles are all very similar throughout the sand layer (Figure 9.4). The sand layer may have been deposited during one or a number of high-speed floods. The sediment underwent selective deposition due to the decreasing energy of the transporting process. In order to deposit the larger fraction (>2 mm) as well as the smaller fraction, the transporting process would have had to have undergone an abrupt decrease in velocity.

9.7 Pollen and Charcoal Analysis of LAP

Sub-samples of 0.5 cm^3 were taken for pollen and microscopic charcoal analysis every 4-8 cm throughout the profile. Samples were prepared using standard procedures (see Chapter Two and Appendix 1).

9.8 Dating Profile LAP

9.8.1 Radiocarbon Dating of LAP

Four samples were submitted for radiocarbon dating. The results are presented in Table 9.1

Table 9.1   **Radiocarbon Dates from LAP**

Depth (in cm below datum)	Lab Code	Radiocarbon yr BP	δ^{13} (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
164-167	Beta-94438	6140±60	-28.2	7004 (7231-6804)	Peat
182.5-185	Beta-94437	8850 ±50	-28.0	10106; 10091; 9914; (10,174-9698)	Peat
237-9	Beta-94436	10,140±100	-32.0	11,734; 11720; 11698 (12342-11260)	*Sphagnum*

Depth (in cm below datum)	Lab Code	Radiocarbon yr BP	δ^{13} (‰)	Calibrated yr BP (2σ, 95%)	Sediment Description
258-9	Beta-94435	11,740±130	-26.2	13,809 (15170-13422)	Organic mud

9.8.2 Optical Thermo-Luminescence Dating (OTL)

A single sample of sand from context 9113 (the trapped sand layer) was dated by Dr Ian Bailiff at the University of Durham, using optical thermo-luminescence dating techniques. Despite the large standard error, the resultant date of 6745±890 years before 1998, is chronologically consistent with the results of the radiocarbon dating from the rest of the stratigraphy (see Section 9.8.1 above).

9.9 Zoning the Pollen Diagram

The pollen diagram was zoned using the computer program CONISS (Grimm 1986). The results are shown in Figure 9.5c. The pollen diagram was then visibly compared to the regional profile D (Chapter Three), with the aid of the radiocarbon dates (above). The LAP zones were then labelled to broadly correlate with profile D, which helps to highlight any hiatuses in the sediment record.

9.10 The Palaeoecological Sequence at LAP

The pollen diagram (Figures 9.5a-b) has been split into four local pollen assemblage zones (prefixed LAP) and described below:

9.10.1 Windermere Interstadial (GI-1) c. 12,000-11,000 ^{14}C yr BP

LPAZ LAP-3   272-254 cm   Betula-Poaceae-Filipendula.

Sedimentation starts at the end of a pre Late-glacial climatic deterioration event. Clastic input is high but decreasing, as soil stabilisation recommences and organic productivity rises. The pollen curve is dominated by inputs from Betula undiff pollen. Betula pollen contributions rise from 40% to 65% of the TLP sum at the beginning of the zone and then gradually decrease to c. 30% by the zone end.

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Poaceae values mirror this pattern by starting at c. 25%, decreasing to c. 15% before rising to again to c. 30% TLP. *Juniperus* and *Salix* are also important pollen producers. Cyperaceae becomes increasingly important rising from 8-20% of the TLP sum by the top of the zone. *Filipendula, Artemisia, Helianthemum* and *Equisetum* all occur in significant numbers. The pollen from all four species peaks in the middle of the zone before declining towards the end. Herb values are high throughout, including pollen from ruderals such as *Plantago* species and *Silene*.

9.10.2 Loch Lomond Stadial and Pre-Boreal (GS-1) c. 11,000–9700 ^{14}C yr BP

Sediments appear to be compacted during the whole of the Loch Lomond Stadial.

LPAZ LAP-4   254-239 cm   Poaceae-Cyperaceae-*Typha latifolia*

Poaceae and Cyperaceae now form the dominant taxa but *Betula* increases from 10-25% through the zone. *Salix, Pinus* and *Filipendula* all rise synchronously with *Betula* but in smaller quantities. *Typha latifolia* forms the dominant vegetation within the lake, peaking at values equivalent to c. 80% of the TLP sum. *Equisetum* is also significant but present in smaller amounts.

9.10.3 Early Mesolithic c. 9700–8800 ^{14}C yr BP

LPAZ LAP-5   239-182 cm   *Betula*-Pteropsida (monolete) undiff.

This zone comprises a single sample at a depth of 200 cm. The pollen count is low, reflecting the low pollen concentration throughout the zone. *Betula* is the dominant woodland species contributing c. 15% of the pollen counted. Spores of Pteropsida (monolete) undiff. are even more abundant and equivalent to 60% of the TLP sum. Poaceae and Cyperaceae are the only other taxa that are either important or recognisable.

9.10.4   Later Mesolithic c. <8800 ^{14}C yr BP

LPAZ LAP-8   167-135 cm   *Alnus glutinosa-Corylus avellana*-Cyperaceae

Corylus avellana is the dominant pollen type contributing over 40% TLP, although its pollen is reduced by 10-15% for 25 cm of the zone, before recovering to its original values by the top of the zone. *Alnus* is already established at 20% TLP at the start of the zone but declines briefly in mid-zone. *Betula* is no longer significant but *Tilia* pollen is consistently present. Cyperaceae peaks during the *Alnus* decline before dropping to insignificant levels by the top of the profile.

9.11 Interpretation of the Radiocarbon Dates from LAP

The top two dates in Table 9.1 are considered to be representative of the sample ages and therefore provide a maximum and minimum age for the deposition of the sand layer. The third date (Beta-94436, 10,140±100 ^{14}C yr BP), which consisted of *Sphagnum* peat is also considered to be correct, as *Sphagnum* peat is an ideal material for radiocarbon dating (Olsson 1986). However, the bottom date of 11,740±130 ^{14}C yr BP appears to be too old on the basis of other published research (e.g. Walker 1995). Housley (1998) observes that because the sample location was in an area of open water "*any radiocarbon determinations on material not specifically identified as terrestrial could be expected to be hard water influenced*" (p31), which would account for the 'artificially old' date obtained for Beta-94435.

9.12 Sediment Accumulation Rates

The average rate of sediment formation at LAP is difficult to ascertain because sediment deposition has been interrupted and truncated at various levels. However, during zone LAP-5, sediment was deposited at a rate of 0.042 cm yr^{-1}. The time-depth curve for profile LAP (see Figure 9.7b) has been constructed using approximate dates for the very top and bottom of the profile. The reasoning behind the choice of dates is discussed in the interpretation of LAP during Section 9.15.

9.13 Pollen Preservation

A pollen preservation curve was constructed (see Figure 9.8) by using the different counts of indeterminable grains.

9.13.1 Zones LAP-3 and LAP-4   c. 271-235 cm

With the exception of sample 267 cm, indeterminable pollen grains account for an equivalent of 40-60% of the TLP sum. Approximately half of the indeterminable pollen sum is attributable to concealed grains, caused by high amounts of metallic sphericals and quartz grains that have resisted the standard treatment with HF. This indicates the deposition of significant clastic inputs within a stable waterlogged environment (Wiltshire *et al* 1994). A substantial proportion of the remaining grains (c. 10-23% TLP), were classified as crumpled, indicating compaction of the

sediments, and possible reworking from other deposits. The remaining pollen grains were either broken or deteriorated indicating erosion and or oxidation of the sediments.

9.13.2 Zone LAP-5   c. 299 cm

This single sample is representative of the entire sediment sequence between 239-182 cm. The relatively large proportion of deteriorated pollen grains (c. 15% TLP) indicates the poor preservation levels within this sediment horizon, which can be attributed to oxidation. This could be caused by either, low water tables during or after sediment deposition, or by repeated wetting and drying of the sediments, perhaps caused by slow sediment accumulation or seasonal fluctuations in the water table. Concealed pollen grains also form a significant component of the assemblage (>15% TLP), caused by resistant organic matter within the lowland peat (Richardson and Hall 1994).

9.13.3 Sand Layer   c. 275 cm

This single sample is taken from the middle of the sand layer. Indeterminable pollen grains are equivalent to approximately 60% of the TLP, with the majority of the grains described as deteriorated or corroded. This implies that the pollen within the sand layer was either eroded and reworked before being deposited at LAP, or that the grains underwent post-depositional oxidation caused by low water levels or very slow sediment accumulation.

9.13.4 Zone LAP-8   c. 167-135 cm

The depositional and post-depositional processes in this zone are similar to those that prevailed during zone LAP-5 (above). In this particular case however, the oxidation of the sediments is ascribed to recent land practices, e.g. drainage.

9.14 The Charcoal Record from LAP

The charcoal record presented in Figure 9.6 shows a constant deposition of charcoal throughout the lower part of profile LAP (the pre-Holocene). This pattern of charcoal accumulation is similar to the charcoal record from zone D-2c to zone D-4a of the regional profile D (Chapter Three). Even the concentration levels are

strikingly similar, typically varying between 50-200 $\times 10^{-5}$ cm^2 cm^{-3}. Since the charcoal concentrations at LAP and Charcoal:pollen ratio do not exceed the regional levels found in profile D, this implies that the charcoal record is predominantly derived from regional rather than local fire sources. Consequently, the charcoal concentration and pollen ratio data provide no evidence to support the long-term human use of fires on the island during pre-Holocene times.

Nonetheless, during the lower part of the profile there are higher than background levels of charcoal particles belonging to the larger size classes, e.g. >8800 μm^2, similar levels during the early Mesolithic, appear to indicate the presence of low stature, small scale, local fires. In the case of LAP however, as there is no evidence for localised fires, these larger particles may be derived from large scale fires that create a substantial smoke plume with enough energy to inject large numbers of larger charcoal particles high into the atmosphere. As charcoal concentrations and Charcoal:pollen ratios are too low to support the concept of local, domestic or low stature fires, then an alternative explanation is that large scale (regional?) fires existed during pre-Holocene times (see also discussion in Edwards *et al* 2000).

In the Charcoal:pollen ratio diagram it is possible to identify three periods of charcoal deposition, although ratios are never more than background levels for this particular zone. Most of this charcoal occurs during the Windermere Interstadial/ Loch Lomond Stadial (zones LAP-3 and beginning of LAP-4). During this period the charcoal concentration curve appears to mirror the birch pollen curve, with charcoal deposition peaking during the stadial-like events when birch pollen values are at their lowest. Charcoal deposition is at its highest at the beginning of the Loch Lomond Stadial (LAP-4) when temperatures were at their lowest (Atkinson *et al* 1987). Later, during the pre-Boreal (top of LAP-4, bottom of LAP-5), the charcoal curve starts to rise at the same time as the increase in *Betula* pollen. A similar pattern has been observed in the regional profile (D, Chapter Three). Unfortunately it has been impossible to identify the charcoal to plant species, due to the small size of the microscopic particles. This suggests that the large scale fires mainly occurred during Stadial-like climatic conditions.

Charcoal concentrations within the early Mesolithic sediments at LAP are also high, but due to the poor preservation status of the sediments no conclusions about local fire activities can be made.

9.15 Synthesis and Human Impact Test 1 - Conventional Interpretation of LAP (Figure 9.9)

9.15.1 Windermere Interglacial c. 13,000-11,000 ^{14}C yr BP

Sedimentation apparently starts at the end of a pre Late-glacial climatic deterioration event (GI-1b or GI-1d, Björck *et al* 1998). Clastic input is high but decreasing, as soil stabilisation recommences and organic productivity rises. Some researchers have suggested that there was a major climatic oscillation (or number of oscillations) between 11,000-11,500 ^{14}C yr BP, termed the Killarney Oscillation in Canada (Levesque *et al* 1993) and the Gerzensee Oscillation in Switzerland (Siegenthaler *et al* 1984; Lotter *et al* 1992). Climatic cooling during this period is thought to have affected the whole of the North Atlantic area (Levesque *et al* 1993). Therefore, despite the results of the AMS dating, the onset of zone LAP-3 probably occurs sometime after 11,500 ^{14}C yr BP with the lowest sample in the profile indicating a period of climatic deterioration. The date of 11,740±130 ^{14}C yr BP is almost certainly too old and has been affected by the hard water in the lake. Pre-Loch Lomond climatic deteriorations are also seen in a number of pollen diagrams from northeast England, e.g. near Star Carr (Day 1996a), Tadcaster in South Yorkshire (Bartley 1962), the sites of Thorpe Bulmer and Kildale Hall (Bartley *et al* 1976; Jones 1977) and Gransmoor Quarry, Holderness (Walker *et al* 1993).

During the Windermere Interstadial the environment was formed of patchy birch scrub (probably *B. pubescens* or hybrids), interspersed with grass and tall herb communities. At first juniper scrub and *Empetrum* heath land, and then later willow scrub (probably *S. cinerea* or *S. atrocinerea*) co-mingled with the birch stands. The constant occurrence of ruderal species such as *Plantago* species, *Silene* sp and *Artemisia* type and the presence of large numbers of crumpled pollen grains, attests to the continued soil de-stabilisation, solifluction or disturbance throughout the zone. The peak and then subsequent decline of *Betula* from 267-246 cm, is probably contemporary with the widespread climatic deterioration at the end of the

Windermere Interstadial c. 11,300-11,000 ^{14}C yr BP (Walker 1995). Comparison with the late-glacial site (K2) at Seamer Carr (Cloutman 1988b) suggests that the organic deposits of the Windermere Interstadial terminated at about 10,960±120 ^{14}C yr BP (CAR-841).

9.15.2 Loch Lomond Stadial/Pre-Boreal c. 11,000-9700 ^{14}C yr BP

It seems likely that apart from the initial climatic deterioration, the most severe climatic events of the Loch-Lomond Stadial are not recorded in the sediments at LAP. This is probably due to decreasing water levels, which resulted in a hiatus at around 254 cm. Sedimentation then recommences after a rise in water level during the subsequent climatic amelioration at the end of the Stadial/beginning of the Pre-Boreal. It seems that there was a tendency for natural fires during the colder periods of the late-glacial, shown by the high levels of charcoal at LAP and in the regional diagram (profile D). High charcoal levels are a feature of many pollen diagrams from the late-glacial in northern Europe, (e.g. van Geel *et al* 1989) and even North America (Maenza-Gmelch 1997). Frequent vegetation fires may have been initiated by the severe climatic conditions that prevailed at that time. The relatively low numbers of local (macro) charcoal pieces and the (regional) charcoal concentration levels argues against a local (island) source for these fires. This also suggests that there was no long-term human use of fire on the island during the late-glacial, regardless of what took place in other areas of the catchment.

In zone LAP-4 (the pre-Boreal) the pollen diagram shows a succession of pollen peaks, first Poaceae and *Typha* species, then Cyperaceae and *Equisetum* followed by *Salix* and *Filipendula*, as the vegetation begins to respond to the ameliorating climate. The establishment of Betula woodland finally succeeded these tall herb and shrub communities. Unlike the regional profile, *Betula*, Poaceae, Cyperaceae and *Rumex acetosa* values are much lower, with minimal *Juniperus,* but instead there is an overall higher diversity of ruderals and herbs contributing to the pollen sum. This may be explicable in terms of the very local aspect of the pollen rain from the island, the higher likelihood of soil destabilisation during the late-glacial upon the island and the early pre-Boreal date for the zone. Charcoal deposition starts to rise at the very top of the zone indicating fires within the catchment, but the charcoal

concentration levels and the charcoal to pollen ratio is too low to imply local occupation.

The high aquatic pollen input during zone LAP-4 reflects the lake margin location of the sediment core. *Typha latifolia* rapidly colonises the inorganic substrate in response to the increased temperatures, followed shortly by *Equisetum* once an organic substrate begins to form. Zone LAP-4 terminates just prior to the start of the Holocene at a date of c. 10,140±100 ^{14}C yr BP (Beta-94436; c. 11,720 cal yr BP), just before *Betula* and *Salix* scrub becomes firmly re-established in the region. This is almost contemporary with the establishment of birch woodland at nearby Roos Bog in Holderness, that occurred just prior to c. 10,120±180 ^{14}C yr BP (Birm-405, Beckett 1981; c. 11,692 cal yr BP). In addition, a horse pre-molar from the sand deposits at Barry's Island has also been dated to c. 10,160±90 ^{14}C yr BP (OxA-6330, Rowley-Conwy *pers com.*), which also confirms the presence of an open grassland environment just prior to re-colonisation by woodland.

9.15.3 Early Mesolithic c. 9700-8850±50 ^{14}C yr BP

Zone LAP-5 is comprised of a single sample at a depth of 200 cm. The sample is swamped with Pteropsida (monolete) undiff. spores and has a very low pollen concentration content, with poor pollen preservation. Exceedingly high inputs from Pteropsida (monolete) undiff are a feature consistent of the results of Smith and Cloutman (1988) and Walker and Godwin (1954) at specific points in the lake hydrosere. Zone LAP-5 has been equated to zone D-5 of the regional diagram, due to the characteristically high levels of Pteropsida (monolete) undiff in D5 (i.e. *Dryopteris filix-mas*), the absence of *Corylus avellana* (easily recognisable even in contexts of poor preservation), and the fact that sedimentation appears continuous after zone LAP-4.

9.15.4 The Sand Layer c. 6745±890 yr before 1998 (OTL)

The dates either side of the sand layer are considered to be representative and provide a maximum and minimum age for the inwash event, i.e. the sand layer was deposited sometime after 8850±50 ^{14}C yr BP (c. 10,000 cal yr BP) but finished before 6140±60 ^{14}C yr BP (c. 7004 cal yr BP). So what caused the formation of the

sand layer and how long after 8850±50 ^{14}C yr BP did the stream form? Particle size analyses in Section 9.6 demonstrated that the sand layer, including flints and bone, was deposited at the point where a high-energy flood or stream discharged into the deeper and slower moving River Derwent. Such a high-energy fluvial event may have been caused by wetter climatic conditions or pluvial episodes. Wetter conditions such as those that occurred after c. 7000 ^{14}C yr BP prompted an increase in fluvial activity, notably flood frequency, which resulted in an increase in stream loading and episodic phases of aggradation and incision (Starkel 1983b, cited in Bell and Walker 1992:105).

It is therefore proposed that after c. 7000 ^{14}C yr BP the sediments at LAP were periodically deposited, eroded and incised until a final phase of incision removed all deposits younger than 8850 ^{14}C yr BP. This was then followed by a period of aggradation that resulted in the deposition of a sand layer during a pluvial phase at approximately 6745±890 yr before 1998 (OTL). This is consistent with the results of a single, low-count pollen sample from peat deposits within the sand layer. The deposits, potentially laid down during an intermission in stream output, imply a post *Alnus* rise date for the stream episode, (i.e. 7600-6160 ^{14}C yr BP using other dates from the catchment; c. 8390-7100 cal yr BP). However it is entirely possible that the pollen sample is derived from organic particles washed through the sand from later deposits.

9.15.5 The Later Mesolithic > c. 6140 ±60 ^{14}C yr BP

Following the deposition of the sand layer, the lake edge environment consisted of alder and sedge carr with mixed hazel-oak-elm woodland on the drier ground. By the end of the sand event *Tilia cordata* was already becoming established on the island, which also confirms the fairly late Mesolithic date of less than 7000 ^{14}C yr BP. The very top of the profile is estimated to date to c. 6000 ^{14}C yr BP before the local establishment of *Fraxinus* (Huntley and Birks 1983) and definitely before the elm decline at approximately 5000 ^{14}C yr BP.

9.16 Sampling of profile LAL

9.16.1 Location

The second profile LAL, was taken from the western side of the island where the land slopes gently away to the west (Figure 9.2). The trench was specifically located in an area where there were no intercalated sand layer deposits, to ensure that the sediments were unaffected by stream action and to maximise the environmental history.

9.16.2 Sample Excavation

The sediment profile was retrieved during the August 1995 archaeological field-season. Samples were retrieved from an open 2x2 m trench using a series of three 0.5 m overlapping monolith tins. The top of each tin was levelled and all measurements were taken from a datum of 25.38 m OD. The tins were then cut from the cleaned east facing section of the trench, wrapped in polythene and then stored at less than 3°C until analysis was possible.

9.17 Lithostratigraphy of LAL

The broad lithology consists of grey basal sands overlain by lake muds, succeeded by carr deposits (see Figure 9.10). The detailed lithology was as follows:

Depth (in cm)	Description
0-108	Unsampled due to dry crumbly oxidised texture of the sediments.
108-233	Orange-light brown organic mud with extensive macrofossil remains of alder, including some carbonised remains.
233-243	Brown organic lake detritus
243-245	Light grey coarse sand

9.18 Pollen Analysis of LAL

Sub-samples of 0.5 cm^3 were taken for pollen analysis at 4 cm intervals, with additional samples taken every 1 cm across the basal transition to lake muds. Samples were prepared for analysis following standard procedures (Chapter Two).

Only the bottom 50 cm of the profile was analysed following interpretation of the preliminary results.

9.19 The Palaeoecological Sequence at LAL

The pollen diagram (Figure 9.10) consists of only one local assemblage zone (prefixed LAL). It has been numbered to broadly correlate with the regional profile D (Chapter Three).

9.19.1 Later Mesolithic c. <7000 ^{14}C yr BP

LPAZ LAL-8   243-200 cm   *Corylus avellana-Alnus-Quercus-Ulmus*

This pollen zone appears to represent a very stable later Mesolithic ecosystem, exhibiting very little variation through time. Alternatively, very rapid accumulation of sediment or post-depositional 'churning' of the deposits may, have created this unchanging pollen zone. *Corylus* is the dominant woodland tree or shrub contributing 40% TLP. *Alnus* percentages already account for 15% TLP at the bottom of the profile, rising sharply immediately above the contact with the basal sands. *Quercus* and *Ulmus* are also important woodland pollen producers at 12% and 6% TLP respectively. By the top of the zone, *Tilia* and *Fraxinus* pollen make a small but significant contribution to the pollen sum. Herb diversity is high including a range of ruderals, e.g. *Silene* and Chenopodiaceae, with herb percentages contributing 15-20% TLP throughout the entire zone.

9.20 Dating Profile LAL

The deposits appear to equate to zone D-8 of the regional profile D (Chapter Three), and detail the composition of the woodland upon the island and the alder carr around it. Due to the apparently young age of the sediments and their potentially 'churned/disturbed' stratigraphy, no radiocarbon dates were obtained for the sequence. However, it is still possible to determine the approximate age of the sediments, by correlating the vegetation sequence with other pollen profiles from the area.

At the top of Day's (1996a) pollen diagram the immigration of alder into the lake area has been dated to c. 7640 ±85 ^{14}C yr BP (OxA-4042), whilst at No Name Hill, the alder rise occurs just prior to 6160 ±50 ^{14}C yr BP (Beta-86147, Chapter Four). As alder is already well established at the base of profile LAL (Figure 9.10), this means that sediment deposition started sometime after c. 7600 ^{14}C yr BP (though potentially as late as c. 6200 ^{14}C yr BP). In either case, at LAL, later Mesolithic/Atlantic sediments appear to lie directly over the basal till sands indicating a major hiatus in sediment deposition.

At 220 cm, near the top of profile, *Fraxinus* and occasionally *Fagus* were just becoming established within areas of secondary woodland. Isopollen maps complied by Huntley and Birks (1983) indicate that within eastern Yorkshire the appearance of *Fraxinus* pollen in low but consistent quantities occurred at approximately 6000 ^{14}C yr BP. Therefore the sediments above 220 cm record the vegetation at Barry's Island after c. 6000 ^{14}C yr BP. At the very top of the profile (200 cm), *Ulmus* pollen is still a significant contributor to the pollen sum, accounting for approximately 6% of the TLP. Consequently, at that point in time the elm decline had not yet occurred and therefore the top of the profile records the environment at sometime before c. 5000 ^{14}C yr BP.

9.21 Sediment Accumulation Rates at LAL

The lack of radiocarbon dates and reliable pollen time markers, makes it virtually impossible to determine the rate of sediment deposition within the sediment sequence. All that can be said is that deposition started sometime after 7600 ^{14}C yr BP and continued until sometime before 5000 ^{14}C yr BP. As the monolith tin spans a stratigraphic depth of 50 cm, then by inference, sediment deposition must have continued at a rate of >0.0192 cm yr^{-1}.i.e., 1 cm every 52 years.

Several lines of evidence suggest that in actual fact the accumulation time was much faster than 52 yr per cm. Firstly, the sediment is highly unhumified which suggests that the deposits were buried rapidly. Secondly, several meters of sediment have been deposited at the site since 7600 ^{14}C yr BP (or later, see Section 9.20 above) and thirdly, the pollen concentration curve is quite low (Figure 9.11), with values of

between 75-50,000 grains cm^{-3} throughout most of the profile. This indicates that the sediment accumulated fairly quickly throughout most of the profile, with the only exception being the very base of the profile. In the latter case, across the bottom 3-4 cm, the pollen concentrations levels are relatively high, peaking at 300,000 grains cm^{-3}, which implies a slow rate of sediment accumulation.

In conclusion, after an initial brief period when the deposits accumulated fairly slowly, the accumulation of sediment at LAL was rapid and almost definitely faster than 1 cm every 52 years.

9.22 Pollen Preservation in LAL

During routine pollen counting a tally of unidentifiable pollen types was kept, based on the categories of Cushing (1967), but see also Chapter Two. Using this information a pollen preservation curve (Figure 9.12) was constructed for this profile. The following observations have been made:

9.22.1 Zone LAL-8   c. 243-200 cm

Unidentifiable pollen trains are equivalent to approximately 20% of the TLP sum with a large contribution (7-12% TLP) caused by partially concealed grains. The concealment of pollen grains is predominantly due to the resistant nature of some of the detrital matter often found in lowland peat (Richardson and Hall 1994). The low contribution from corroded, crumpled and broken grains demonstrates that the sediments have suffered little oxidation, compaction or erosion.

9.23 Synthesis and Human Impact Test 1 – Conventional Interpretation of Profile LAL (Figure 9.10)

In profile LAL, Late Mesolithic/Atlantic sediments directly overlie the basal late-glacial sands. The deposits relate to zone D-8 of the regional profile (Chapter Three) and detail the composition of alder carr around the island and woodland upon it. Only a major event would account for the loss of all the early Holocene sediments along the western side of the island. It is therefore postulated that the same stream

responsible for the reworking of older sediments along the north of the island, must also be responsible for the sediment hiatus at LAL.

Following this event, alder carr gradually colonised the newly uncovered basal sediments at the island margins, at a time when alder carr was already well established elsewhere in the catchment. Upon the dry land, contemporary with the alder carr, a mixed hazel, oak and elm woodland developed with a fairly substantial component of lime on the moist but fertile soils. Towards the top of the profile, ash was just becoming established within areas of secondary woodland, indicating the deposits are less than 6000 years old (c.f. Huntley and Birks 1983). The diversity and percentage (c. 15-20% TLP) of the herb layer, including a range of ruderals, e.g. *Silene* and Chenopodiaceae, implies areas of destabilised soil or ground disturbance. These may be attributable to disturbances by later Mesolithic peoples, wild animals, e.g. wild pigs or a natural peat slide.

Even though the diagram has only been sampled at 4 cm intervals, the pollen curves do not appear to fluctuate or vary to any great degree. This may indicate very rapid accumulation or mixing of the sediments. In actual fact, 2.35 m of sediment has developed at the site since the *Alnus* rise (7640±85-6160±50 ^{14}C yr BP), which supports the former interpretation (see also Sections 9.21).

9.24 Combined Interpretation of the events at Barry's Island.

Combining the results of the particle size, metals and pollen analysis allows some of the anomalous results at Barry's Island to be interpreted within a wider context:

Sedimentation at the lake edge commenced during the middle of the Windermere Interstadial sometime after 12,000 ^{14}C yr BP and is preserved, despite several sedimentary interruptions, until the very late Mesolithic (LPAZ LAP-8). During the lower part of the diagram, the vegetation follows the broad regional pattern described in Chapter Three, but with a higher contribution from herb and ruderal species presumably reflecting pollen rain from the local vegetation. The high charcoal deposition in the pre-Holocene sediments correlates well with the regional

picture, increasing during periods of low tree cover and deceasing during more temperate episodes. It demonstrates the regional and not necessarily local origins of the fires. There does not appear to be any proof for late-glacial human use of the island, e.g. lack of flints and macro charcoal, although the problems of linking late-glacial vegetation disturbance to human populations are extensive (Moore 1979b).

The abrupt cessation of pollen preservation above 239 cm at LAP and the lack of pollen preservation in zone LAP-5, accompanied by the elevated levels of fern spores requires some explanation. High levels of Pteropsida (monolete) undiff occur in all the profiles analysed in this thesis, especially within deposits with low pollen concentrations or preservation, usually at the top of the profiles (e.g. Profile D and NM). In all the profiles this fern layer appears to correspond to a particular period during the hydrosere and overgrowth of the lake, i.e. during the formation of sedge peat. Analysis of LAP and NM (No Name Hill, Chapter Four) shows that the fern horizon is succeeded by the formation of alder carr, accompanied by slightly higher pollen concentration values. It is proposed that the fern horizon first occurs at a point in the hydrosere when marsh and reed-swamp has already developed, but where the ground is not permanently water logged. The presence of *Hydrocotyle* at NM zone NM-8, attests to the absence of permanently waterlogged conditions (c.f. Grime *et al* 1991). Aerobic conditions throughout some of the year would allow bacterial action to corrode the pollen grains and decrease their concentration throughout the deposits. Pteropsida (monolete) undiff. spores, (i.e. originally *Thelypteris palustris*) are much more resistant to decay and therefore the number of spores relative to pollen would become enhanced within the deposits. It is not until a period of higher water levels or litter production that pollen concentration and preservation levels recover.

Along the northern sector of the island the poorly preserved deposits are directly overlain by a thick layer of iron-stained sand, (context 9113). Particle size analysis has demonstrated that a high-energy stream deposited the sand sometime during the later Mesolithic. Coulton Beck (the present day name of the palaeostream/spring), was a shifting and episodic streambed, which is now channelised, and feeds into the present course of the River Derwent. The precursor to the Coulton Beck was one of a series of relict channels that emerged from the foot of the Wolds c. 200 m apart,

running northwards towards the centre of the Vale. *"The course of the latter [palaeostream]* *has now been identified as a palaeochannel in the degrading peat running from the scarp of the Wolds at least as far as Barry's Island some 1km to the north. The palaeochannel is visible on aerial photographs and from vantage points on top of the Wolds"* (Lane 1998:73).

In the Vale of Pickering, several climatic shifts may have combined together to produce the reworking of the archaeological deposits and truncation of the sediment history on and around Barry's Island. A number of wet and dry shifts in climate have been observed from studies of Holocene palaeochannels, e.g. Kirkpatrick Fleming in Scotland (Tipping 1995) and are also likely to have occurred across other areas of Britain. During a substantial shift to wetter conditions, e.g. 8800-8500 and 8250-7700 ^{14}C yr BP, increased discharges may have led to down cutting of sediments particularly if lateral channel migration and sediment supply were restricted (Tipping 1995). This would account for the removal of the early Holocene sediments on the western side of the island at LAL and the truncation of sediments at 8850±50 ^{14}C yr BP at LAP.

Slightly later, during another period of increased discharge, context 9113 (the sand layer) was formed. The particle size data from context 9113 (Section 9.6 above), infers the stream current had a high competence, which in addition to and as a consequence of the high velocity of the traction load, led to further downward erosion of the peat surface. In turn, this exacerbated the formation of the deep channel on the western side of the island and resulted in the churned surface of the underlying peat. When the stream met the deeper channel of the pre-Holocene River Derwent on the north edge of the island, the stream dropped its bed load as a sand layer over the peat. In order to flow over the peat, the vegetation would have to be fairly dry, low lying and easily flattened. This is in keeping with the hypothesised environment of seasonally dry sedge peat occurring in other areas of the catchment during the later Mesolithic (see above). The poor pollen preservation in zone LAP-5 (discussed above) is also likely to have been exacerbated by the formation of the sand layer. The incision of a large channel within the peat would have caused a drop in the water level in the adjacent peat and seriously affected the organic preservation

of their sediments. It also accounts for the somewhat 'patchy' pollen preservation observed across the island deposits.

The sand layer has been dated to 6745±890 yr before 1998 using Thermo-Luminescence Dating (Section 9.8.2). Despite the large standard error for the date, the discharge event almost undoubtedly occurred sometime between 7000-6000 ^{14}C yr BP, as before and after these periods there were phases of decreased discharge and precipitation across much of Europe (Starkel 1984, 1991). One of the main phases of Holocene alluviation during the Atlantic, took place between 7200-6800 ^{14}C yr BP (Macklin and Needham 1992) which provides a potential timeframe for this event. Stable isotope variations also indicate that particularly wet conditions occurred in Scotland c. 7500 and 6250-5800 ^{14}C yr BP (Dubois and Ferguson 1985) which could also provide possible dates for the discharge event. Finally the discharge event (s) may be caused by the same factors which were responsible for a rise in water level or change to a wetter climatic regime at Mixnam's Ferry, Thorpe in Surrey, which has been dated to just after 6650±55 ^{14}C yr BP (Q-2043) (Preece and Robinson 1982, cited in Chambers *et al* 1996:12) with similar changes also occurring at Enfield Lock at 6620±50 ^{14}C yr BP (Chambers *et al* 1996:12).

Following the Coulton Beck episode, floodplain stabilisation allowed peat growth and sedimentation to take place within the palaeochannel. Consequently by c. 6140±60 ^{14}C yr BP, alder carr grew extensively over the island, directly onto the sand layer and within the palaeochannel of the Coulton Beck. This is demonstrated by the presence of plant macrofossils from LAL and in the field macrofossil and pollen analysis from other parts of the island.

9.25 Human Settlement at Barry's Island: Conclusions

No inferences about the early Mesolithic occupation of Barry's Island can be made, despite the analysis of two pollen cores. This is a direct result of the complex depositional history of the island and its associated spring fed stream(s). It is highly possible that any human occupation of the island was limited to occasional and isolated episodes of flint knapping, seen from the lithic evidence at LAO, LYY and

LG. If any other occupation of the island had occurred during the early Mesolithic it is unlikely to have been very extensive as the island was too restrictive in size to allow for long-term settlement. Instead, the island may have been used as a convenient location to butchering carcasses and dry meat, possibly following water driven hunting expeditions (Utchiyama 1996). It would definitely have provided a secure place to dry and process meat away from scavengers and predators.

To date, there is also no evidence to support any Upper Palaeolithic human occupation of Barry's Island. The presence of high levels of microscopic charcoal, if derived from human activity, does however suggest that there may have been an area of Upper Palaeolithic settlement along the south-eastern section of palaeo-Lake Flixton that still awaits discovery (but see charcoal discussion in Chapter Ten). Later Mesolithic occupation along the south-eastern lake margins and upon the former island is also likely, indicated by extensive faunal and lithic artefacts contained within the sand layer and upper contexts. Burning of alder carr after 6140 ±60 ^{14}C yr BP is also substantiated by the presence of burnt alder remains within the upper horizons at LAL.

9.26 Comparison with the regional vegetation (Chapter Three)

Zones LAP-4 and LAP-3 equate to zones D-4a, D-3 and the very top of zone D-2c from the regional profile D. The vegetation history and charcoal profiles are strikingly similar, probably as a result of pollen and charcoal transport within a semi-open environment. As would be expected, slightly more information is available about the lake-edge vegetation at LAP, which shows the importance of sedges, water horsetail and bulrush.

Further comparison between the two profiles reveals that the sediments in zone LAP-8 appear to correspond to the vegetation from midway through zone D-8 of the regional profile at c. 275 cm. It is at this point that *Tilia* becomes a consistent component of the woodland vegetation. Not surprisingly, zone LAL-8 from profile LAL also appears to equate to the same point in the regional profile.

9.27 Comparison with Star Carr

The vegetation profiles from LAP and LAL are not comparable to the vegetation profiles from the site of Star Carr, due to the absence of contemporary deposits.

9.28 Comparison with the Rest of the Vale

With the exception of a very coarse resolution pollen diagram from K2, Seamer Carr (Cloutman 1988b), sites PCC and QAA are the only other sites in the Vale of Pickering which record details of the late-glacial environment at the lake edge (Cummins 2000b, 2001). Profiles PCC and QAA (Figures 9.14 and 9.15) provide a very detailed record of the vegetation throughout the entire Windermere Interstadial and succeeding Loch Lomond Stadial. Comparison of the three profiles demonstrate that the environments along the lake edge and island edges were very similar probably explicable by pollen transport within a relatively open landscape. The continual deposition of high concentrations of charcoal at all sites provides yet more evidence for large-scale regional fires rather than small-scale local fires during pre-Holocene times. However, differences in the timing of certain temporally discrete episodes of fire activity may suggest that at certain times fires were restricted to particular local areas.

No other sites in the Vale of Pickering are directly comparable to the upper sediments at LAP.

9.29 Wider Issues

The cessation of sediment deposition during the period corresponding to the Loch Lomond Stadial is assumed to be due to natural hydrosere progression at LAP. The coldest part of the Loch Lomond Stadial must have been succeeded by a period of higher water levels as the sedimentary sequence recommences at the start of the Pre-Boreal. Similar water level changes have been observed at PCC and QAA along the southern edge of palaeo-lake Flixton (Cummins 2000b, 2001) and water level changes are also observable in the regional profile D (Chapter Three).

9.30 Chapter Nine - Summary

The main pertinent points to arise from this chapter are:

- There is no evidence for local fires during the Pre-Holocene and there was no discernible late-glacial human occupation of Barry's Island.

- The deposition of pronounced Pre-Holocene charcoal peaks in a number of profiles from across the Vale suggests the occurrence of large-scale regional fires rather than small-scale local fires during pre-Holocene times.

- These fires predominantly occur during cold Stadial –like events.

- Differences in the timing of certain temporally discrete episodes of pre-Holocene fire activity may suggest that at certain times fires were restricted to particular local areas.

- The start of the pre-Boreal at Barry's Island has been dated to just after $10,140\pm100$ ^{14}C yr BP or 11,734, 11720, 11,698 cal yr BP.

- Determining the exact location of the early Mesolithic sites on Barry's Island was problematic due to the complex sediment history upon the island.

- Three discrete and *in situ* early Mesolithic flint scatters were eventually discovered, and one episode actually took place in amongst the reedbeds at the lake edge.

- The faunal data is composed of a large number of bones of varying ages, dating from the Final Palaeolithic up until the end of the Mesolithic. As least some of the some of the human activity during these times occurred in the late autumn and winter periods.

- Despite the evidence for an early Mesolithic human presence on the island, there is no evidence to support the idea that early Mesolithic occupants changed the vegetation in any way. This is due to poor pollen preservation conditions during zone-5 in profile LAP, and the absence of early Mesolithic sediments in profile LAL.

- Charcoal concentrations within the early Mesolithic sediments at LAP are high, but due to the poor preservation status of the sediments no conculsions about local fire activities can be made.

- The low pollen preservation levels within the early Mesolithic sediments of LAP are attributed to seasonally dry conditions within the *in situ* sedge carr.

- A high velocity stream (palaeo-Coulton Beck) or major flood event(s) occurring c. 6745±890 yr before 1998, was responsible for the removal of the early and later Mesolithic sediments along the western side of the island.

- After c. 6140±60 ^{14}C yr BP, alder carr grew directly on top of the basal sands along the western side of the island. This was made possible as the palaeo-Coulton Beck removed much of the earlier sedimentation.

- Humans may have been responsible for the burning of alder carr at Barry's Island after 6140±60 ^{14}C yr BP, shown by the presence of burnt alder remains within the upper horizons at LAL.

Chapter 10 - Discussion and Summary of Findings

10.0 Introduction

The last six chapters have investigated the vegetation history and human impacts at three previously un-researched sites around palaeo-Lake Flixton. The use of statistical analysis has helped to refine the interpretation of the effects of human impact. This chapter summarizes the main findings about the environment, vegetation history and human impact at these three sites, from the terminal Palaeolithic until the latest Mesolithic. The work is interpreted within the context of the archaeology and other palaeoecological work from the area. Periods of early Mesolithic occupation will be compared and contrasted with Star Carr and an attempt will be made to reconstruct the individual processes and range of economic strategies that might have been employed in the early post-glacial. It will then be possible to determine whether these economic strategies evolved from the preceding Upper Palaeolithic or progressively evolved during the Mesolithic.

This thesis, which investigates the eastern and southern edges of the lake, complements the work of other authors, e.g. Cloutman (1988a, 1988b); Cloutman and Smith (1988); Day (1993, 1996a, 1996b); Innes (1994); Day and Mellars (1994); Mellars and Dark (1998). In contrast, their combined research has enabled a good representative reconstruction of the vegetation along the western and northwestern edges of the former lake. This thesis also allows detailed investigation of some the wide-ranging issues raised by those papers, e.g. the early establishment of alder (see Chapter Eleven). The problems encountered within this study, which are also applicable to other studies of this nature, are also addressed.

10.1 Problems Encountered

10.1.1 Preservation

Poor microfossil preservation necessitated that all profiles were taken from peats, at varying distances from the archaeologically rich layers. In fact in 1995 it was necessary to dig approximately 30 m away from the shore at No Name Hill in order to achieve the same levels of preservation that existed 10 m from the Star Carr shoreline in 1989. Although digging further from the ancient shoreline ensured that it was possible to construct statistically valid pollen diagrams, it also produced a number of drawbacks. These were:

    i.   it diminished the amount of intercalated archaeological information

    ii.   it lessened the degree of human impact that was recorded,

    iii. the number of terrestrial macrofossils that were contained in each profile declined with distance and thus the 'datability' of the profile and its phases of human occupation were compromised

In addition to the depth of burial, pollen preservation is also dependent on the nature of the depositional environment. Many of the profiles are interrupted by a layer of poorly preserved sediment, which was deposited during periods of reduced water level or seasonally dry conditions, that were not conducive to organic preservation e.g. LAP zone-5 and NM zone-8. The moisture content of the sediments also appears to be very important, and probably much more critical than the pH of the sediments. For example, the moisture-rich calcareous marls of D3 contain pollen that is extremely well preserved, compared to the drier, more acidic lake edge sediments where pollen preservation is poor. Lack of liming of the ground to the north of No Name Hill (at NAQ) compared to frequent liming of the field at Flixton School (FS) has also had a negligible effect on the depth of pollen preservation. This reinforces the hypothesis that water content is probably the most critical element to affect microfossil preservation.

In summary, at the lake edge well-preserved early Mesolithic sediments are only likely to be contained within the 'permanent water saturation level' of the peat. The

threshold depth for preservation will no doubt continue to decline, as the combined effects of ploughing and drainage continue to lower the water level within the peat.

10.1.2 Detecting Climate change v Human impact

Equifinality is a recurrent theme in palaeoecology and the major problem facing palynologists trying to detect human impact in the environmental record. This has become particularly apparent during this study, as the background variations in pollen production during the early Mesolithic are so great that it makes it very hard to distinguish the human impact from the climatic variations, despite the presence of charcoal peaks (see Chapter Three). In addition, fine resolution analyses from the Deep Profile (Chapter Three) have shown that herb diversity and abundance is a factor of sample resolution, as it increases with increased sampling resolution. Thus even at the lake-edges, despite the presence of local charcoal, it is often hard to isolate the human induced changes from these background variations.

In order to differentiate between the effects of human and climatic events, statistical analyses were employed. Such analyses were useful to identify the range of expected background variations in the pollen data from profile D and apply these to the lake edge profiles e.g. Human Impact Test 3 (Chapters Three - Eight). Using this model it was possible to fine-tune the interpretation of human impact. Unfortunately, the very species that are conventionally used as indicators of human disturbance (e.g. woodland edge shrubs and herbs of disturbed ground), had to be omitted from the statistical analyses because their low pollen percentages precluded analyses. Consequently, although statistics made it easier to identify periods of significant disturbance to the principal taxa, it was impossible to conclude anything about the small associated changes to the herb and shrub flora.

The model put forward in Chapter Three (Human Impact Test 3) appears to work relatively well, however a non-linear regression curve is sometimes more appropriate. The use of solely linear regression lines sometimes causes anomalies within the data,

although these have been identified whenever possible. If the model were to be used again, then polynomial or other appropriate curves should be used where necessary.

During conventional interpretation of pollen curves, analysis of human impact rarely considers the effect of background pollen variations. This model (Test 3) has allowed for these variations, but in main, it has supported the conclusions of the conventional analyses, although to a smaller degree.

Within this thesis and other work relying on microscopic charcoal, the interpretation of the charcoal curves is limited by current knowledge about charcoal taphonomy. The results presented here have been interpreted assuming that the visible charcoal curve is an adequate reflection of past activity. The author accepts that future charcoal research may demonstrate that there is little link between charcoal deposition and the length or intensity of human occupation. However, in the absence of research, the charcoal profiles have been interpreted assuming that all charcoal has been deposited *in situ* and within the sample resolution.

10.2 Results from the Late Upper Palaeolithic > c. 11,550 cal yr BP

10.2.1 The Windermere Interstadial (GI-1 >c. 12,445 cal yr BP or 14,700-12,650 GRIP yr BP)

There appears to be no organic sedimentation prior to this period, with any lake infilling probably the result of hillwash and cryoturbation. Before the start of the Interstadial, it is assumed that the vegetation was similar to other parts of northern England. From profile D (Chapter Three) and Day's (1996a) profile, it can be seen that organic sedimentation began at c. 13,000 ^{14}C yr BP, although climatic amelioration probably occurred some 800 years earlier (Coope and Brophy 1972; Brooks *et al* 1997).

The warmer periods of the Interstadial saw the stabilisation of soils by closed grassland and scrub, with the latter being dominated by birch and scattered willow.

Birch frequencies sometimes get high enough to suggest open birch woodland. At times, *Typha latifolia,* a pioneer plant on inorganic soils was able to colonise some areas of the lake edge. During the colder phases birch woodland receded and was replaced in part by juniper scrub and rockrose. One such cold phase occurred at approximately 11,800-12,000 ^{14}C yr BP, a period which may potentially be correlated with various other proxy records from the northern hemisphere, e.g. GI-1b dated to 13,130-12,880 GRIP ice core yr (Björck *et al* 1998). This cold period was succeeded by yet another warm phase just before the beginning of the cold conditions that marked the start of the Loch Lomond Stadial. During this last climatic amelioration birch frequencies reach their peak for the Interstadial, suggesting the development of open birch woodland once more.

10.2.2 Loch Lomond Stadial (GS-1 <12,445-11,550 cal yr BP or 12,650-11,500 GRIP yr BP)

By the very end of the Upper Palaeolithic (the terminal Palaeolithic), the climate had deteriorated and the stadial conditions of the Loch Lomond Stadial prevailed. There may have been hiatuses in the lake sedimentary record during this period as mineral movement was high and the lake seasonally frozen. Despite this, the deposits follow the normal sequence for this region, which is a cold period when periglacial conditions prevailed. The sediments are mostly minerogenic but pollen counts show an open landscape with few trees. There is little evidence for the development of large amounts of aquatic vegetation and so the high frequencies of grass and sedge pollen are probably reflective of extensive stands of terrestrial vegetation (see Mellars and Dark 1998:178). However, the deposits also contain very high levels of charcoal, indicating that fires were frequent within the region, regardless of their origin. Towards the end of the Loch Lomond Stadial some amelioration of the climate took place about 600 years before the main Loch Lomond Stadial/Pre-boreal transition (Björck *et al* 1996).

10.2.3 Human Occupation of the eastern Vale of Pickering in the pre-Holocene

Lithic scatters demonstrate that there were a few Upper Palaeolithic sites around the lake prior to the Holocene (Lane 1998; Conneller 2000a,b; see also Figure 10.1). All

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the sites appear to indicate very brief visitations by human groups from outside the area. Lower sea levels meant that there was unrestricted access to England from the continent and Conneller (2000a,b) suggests that the expeditions were undertaken to explore new areas. The travellers equipped themselves with provisions e.g. till flint from the North Sea Plain, as they were unsure of the environment and supply of raw materials and food within the exploratory area. Conneller believes the lithic scatters are derived from very short-term, single episode activities such as hunting or they were used as fighting equipment, made specifically for use on exploratory expeditions.

After c. 12,445 cal yr BP during the cold climatic conditions of the Loch Lomond Stadial, the seasonal temperatures were extreme and mean January temperatures were c. -20°C (Atkinson *et al* 1987), compared to an average of c. 4°C for the present day. Winter occupation of the Vale by human groups therefore seems unlikely, although seasonal summer trips may still have occurred.

10.2.4 Origins of the Pre-Holocene Charcoal.

Throughout the Windermere Interstadial and Loch Lomond Stadial, charcoal concentrations are very high. Fires appear to have occurred frequently at LAP and D3, especially during the colder climatic episodes (Figure 3.5, Chapter Three and Figure 9.9, Chapter Nine). This pattern is clear from profiles PCC and QAA along the southern lake-shore (Figures 9.13 and 9.14) and is also seen in parts of Scotland (Edwards *et al* 2000). The origin of the fires is difficult to define, as the complex and variable climatic conditions that prevailed during the Windermere Interstadial are not fully understood. Charcoal deposition at this time could be attributed to any one or a combination of several factors:

i. Dry cyclonic conditions – an increase in the number of dry cyclones may have led to increased lightening strikes and caused extensive natural fires, particularly on the continental heath and steppe like vegetation.

ii. Human activity - human groups may have lit domestic fires or deliberately set fire to the steppe or scrub woodland.

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iii.   Secondary charcoal - a change in the taphonomic processes within the lake may have led to an increase in the amount of charcoal transported to the centre of the lake. Equally there may be an increase in the amount of charcoal derived from secondary deposits.

All these factors will be considered separately below.

10.2.4.1   Charcoal derived from Human Activities

If some of the charcoal deposited during the early part of the Windermere Interstadial and Loch Lomond Stadial originated from human activity, i.e. land-based fire or domestic fires, this implies an early human presence in the North of England. So far, the oldest site to have been found in the Vale is the Late Upper Palaeolithic Site K (Schadla-Hall 1987a), which is dated to 11,000±130 ^{14}C yr BP (HAR-5242). Despite the lack of artefactual evidence, an earlier human presence is not impossible as only a small portion of the Vale has been extensively excavated.

The earliest Upper Palaeolithic sites in Northern England date from just before 12,000 ^{14}C yr BP to after 11,000 ^{14}C yr BP, but are mostly from caves (e.g. Victoria Cave, Settle and Creswell Crags in Nottinghamshire). A barbed point from nearby Gransmoor, has been dated to between 11,000-11,500 ^{14}C yr BP (Sheldrick *et al* 1997). Elsewhere in the north of England people were present during the late-glacial in Cumbria (Ashmead 1974; Salisbury 1988) and during the winter of the Windermere Interstadial at High Furlong in Lancashire (Hallam *et al* 1973). In addition Creswellian industries were present in Northern England from c. 12,600 ^{14}C yr BP, up to north Lancashire (Housley 1991; Barton 1997; Housley *et al* 1997). However, the warmest climatic periods, the time when one would most expect a human presence in the area, correspond to the lowest periods of charcoal deposition in Profile D.

In support of the hypothesis that charcoal is derived from human activities, is the fact that Day's (1996a) profile contains much lower levels of charcoal than those recorded at Profile D. This suggests that the charcoal is derived from variable local fires rather than

large-scale regional fires. When charcoal peaks do occur, i.e. at c. 12,000 ^{14} C yr BP in zone S-3a, Dark (1998) proposes that " *Birch may have been affected for a time by burning, presumably linked to human activity*". She then goes on to say that, *"It is possible that some areas of open woodland and scrub were burned, either due to accidental spread of fire from hearths, or deliberately, perhaps in an attempt to increase vegetation productivity and so attract game"* (Mellars and Dark 1998:179-180). Bos and Janssen (1996) have also attributed similar late-glacial charcoal peaks, to the activities of prehistoric hunter-gatherers at Milheeze in the Netherlands, although they propose that the charcoal is mainly derived from domestic fires.

However, with a fairly diverse and open landscape, is burning of the land a likely strategy? Hicks (1993) stresses that people pursuing a purely hunter-gathering economy and moving in forests (and probably open woodlands), behave in a manner designed to preserve rather than destroy their environment. In an environment that is not totally wooded, *"wood would have been a prized and essential commodity, extensive fires would have been guarded against at all costs "*(Hicks 1993:138). There no reason to suspect that people in the Vale of Pickering would have had a different attitude, in what would have been a partially wooded or open environment.

The fairly open scrub woodland would mean hunters could openly track herds of animals, whilst the latter would periodically congregate near water in the sheltered Vale, reducing the need for land management to predict herd movements. Consequently, there would be no need to burn certain areas of land as has been suggested for the post-glacial period (Mellars 1976; Jacobi *et al* 1976). Pollen grains indicative of grazing and pasture e.g. *Plantago major, Succisa, Potentilla* and *Ranunculus* are of little help here, as they would have occurred due to the prevailing climatic conditions.

If large scale burning by hunter gatherers did occur, it is likely to have been related to game driving of horse or reindeer, perhaps into the lake, e.g. Anell (1969), cited in Utchiyama (1996). Or to purposely create areas of lush growth to attract herds, as documented in the ethnographic data from Eastern America (Lewis and Fergusson

1988). This would suggest that grassland fires would have been more likely as opposed to woodland fires. Lewis (1982) states that in northern Alberta the Indians used to set fire to the grasslands in early spring. Burning at such a time, encouraged the early growth of grasses and brought forward the growing season by 2-3 weeks. This would be highly advantageous in environments with short-growing seasons and forms a very plausible reason for firing of the grasslands in the late Upper Palaeolithic.

The only other reason for firing the land would be to encourage herbs and vegetable resources (Bradley 1978). Grassland burning on acid and sandy soils is a possibility, as these would derive the most benefits from burning (Williams, C. 1985). However, lack of soil development and fragile soils would have been a problem in some areas during the Interstadial and burning would only exacerbate this problem. There is also no convincing evidence for large quantities of fire resistant taxa during this period.

If the vegetation was not deliberately (or accidentally) fired, then this leaves a purely domestic origin for the charcoal. Edwards and Ralston (1984) propose that domestic charcoal should demonstrate the intensity of occupation, although Clark and Royall (1995) argue that domestic hearth fires would not be able to produce significant quantities of charcoal, and not enough to register a strong signal in the sediments. The charcoal signal in zones D-1 to D-3 is much higher than known periods of occupation within the early Mesolithic, so if the charcoal was derived from domestic fires then vast populations and intensive use of the area would have to be envisaged. This seems at odds to the comparative lack of early Mesolithic charcoal recorded in the lake centre. Furthermore, Hicks (1993) and Bos and Janssen (1996), who both cite domestic origins for their charcoal, most clearly see human impact within 50-150 m of the cultural/archaeological deposits. Unless a widely different or more intense economic strategy were in place, then Upper Palaeolithic domestic charcoal is unlikely to have been perceptible at greater than 400 m (Day 1996a) and definitely not 750-1000 m (this volume).

In summary, if the pre-Holocene charcoal record is derived from human activities then it is most likely to have been caused by large-scale (hunting-related) fire activities rather than domestic fires, although there is no direct evidence to support this.

10.2.4.2 Climate related fire events

As an alternative, the charcoal deposition may be mostly climatic in origin, with extensive fires caused by the dry, unstable climatic conditions that prevailed at the time. At present little is known about the carbon stores, atmospheric carbon and climatic regimes that prevailed during the Late-glacial and preceding Windermere Interstadial. Dry-period continental steppe fires may have been widespread. During the pre-Holocene the Vale of Pickering would have had a much more continental climate as sea levels were much lower c. > 100m below the present (Lambeck 1995; see Figure 3.11).

The occurrence of fires *"...is controlled by the presence of dry fuels, an ignition source and wind, but fire susceptibility is governed by the position of warm air streams.."* (Tipping 1996:53). During the Late-glacial, surface air circulation was westerly and there was increased depression activity over the North Atlantic (Isarin *et al* 1998). Consequently, anti-cyclones persisting in summer might have created dry conditions favourable to natural fires. The same scenario has been suggested for other parts of post-glacial Britain, e.g. Gear (1989) for Loch Mer and Whickham-Jones (1990) for Rhum.

If charcoal levels are due to climate, e.g. an arid environment, what evidence is there for this? The continual deposition of high concentrations of charcoal at D3, LAP (Chapters Three and Nine) and PCC and QAA (Cummins 2000b, 2001) provides support for the hypothesis of large-scale regional fires at this time. The large-scale intense burning of vegetation inferred by Day (1996a) during the late-glacial, is also consistent with natural steppe fires. High charcoal levels are also a feature of many pollen diagrams from the Late-glacial and preceding Interstadial from northern Europe including Usselo, Netherlands (van Geel *et al* 1989), Milheeze in the Netherlands (Bos

and Janssen 1996), Northeast Germany (Behre 1988), and even North America (Maenza-Gmelch 1997).

Explanations for these climatic traits have been suggested by Sissons (1979) and Huntley and Birks (1983). Sissons proposes that precipitation diminished over short distances from ice sheets with parts of Scotland receiving only 200-300 mm yr^{-1}, while Huntley and Birks (1983) proposed that climatic gradients were sharper and very different from today. This has been confirmed by recent work on Coleopteran data by Coope et al (1998) and Witte et al (1998). These results also indicate a higher radiation receipt and stronger seasonality compared with the present day. A number of lines of proxy evidence also infer periods of aridity in Britain and North-west Europe at this time (e.g. Coope and Brophy 1972; Beckett 1981; Walker and Lowe 1990; Tipping 1991; Bohncke and Vandenberghe 1991; Isarin et al 1998).

In support of this theory, fire does seem to occur at the same time as extensive tracts of grassland and heathland, which are readily combustible (Tipping 1996). In profile D, the peaks in charcoal concentrations correlate well with low levels for *Betula* throughout the Interstadial, which may indicate increased aridity during colder climatic periods. In addition, the highest charcoal levels are at the very start of the climatic amelioration, at a time when significant climatic fluctuations are likely. Nonetheless, these periods are also associated with high Cyperaceae levels. *"There is little evidence for the development of extensive stands of aquatic vegetation other than algae and probably Chara"* (Mellars and Dark 1998: 175) within lake Flixton in the late-glacial. This suggests that the high levels of Cyperaceae within the pre-Holocene deposits are derived from land sedges growing within extensive grassland and heaths. Huntley and Birks (1983) state that burning is thought to be detrimental to Cyperaceae and many *Rumex* species also do not favour arid conditions. As high Cyperaceae and *R. acetosa* levels are a feature of the Windermere Interstadial, it does cast doubt on the theory of frequent natural fires within the landscape (Figure 3.4a).

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It also seems odd that charcoal is generally sparse in the late-glacial and early Holocene deposits near Star Carr (Day 1996a:19), although charcoal does occur consistently for a period during the middle of the Windermere Interstadial (lower half of sub-zone S3-a). How could large-scale fires produce somewhat localised fire histories? The answer may well be dependent on differences in the taphonomic history of the charcoal between the two sites. Research by Whitlock and Millspaugh (1996) has revealed that charcoal deposition is different throughout transects across lakes, dependant on charcoal taphonomy. This is principally caused by wind generated water currents, with the result that more charcoal should be deposited on the downwind side of the lake. If the dominant prevailing wind was from the west during the pre-Holocene (as stated by Isarin et al 1998), then this would provide a satisfactory explanation for some of the observed charcoal patterns. In fact, both aeolian data (dune morphology) from Europe and model simulations suggest that the atmospheric circulation during the Younger Dryas (Loch Lomond) was characterised by strengthened westerly flow and increased depression activity over the North Atlantic (Ressen et al 1996; Isarin et al 1997; Bateman and Huissteden 1999; Hammarlund et al 1999).

The sampling interval of a profile will also determine the number of fire events that are recognizable within a profile, which could provide yet another explanation for the anomalous Upper Palaeolithic charcoal results. The continual charcoal levels in profile D and LAP are likely to be due to the sample resolution being greater than the fire frequency. This results in a continual and smoothed charcoal curve, when in reality there may have only been a few widely spaced fires.

10.2.4.3 Erosion

Finally, erosion or reworking of pre-Devensian deposits may provide an explanation for the high charcoal values, as there seem to be flaws in both the arguments for anthropogenic fires and climatic fires. Owing to the importance of secondary charcoal (Whitlock and Millspaugh 1996; Bradbury 1996), the degree of soil instability also needs to be taken into account, and may explain the different charcoal signatures at D3 and Star Carr. In support of this idea, peaks in Pre-Quaternary spores can be correlated

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to some but not all of the charcoal peaks at the different sites and Petra Dark documents redeposited charcoal fragments in the basal sediments of her lake centre profile, (Mellars and Dark 1998:Chapter 14).

High charcoal concentrations might also be explained by the high influx of sand and mineral particles to the sediments. Sand has been shown in experiments to concentrate charcoal particle deposition (Nichols *et al* 1997). This may partly explain the association of charcoal with less temperate/stadial climate conditions.

10.2.4.4 Late Upper Palaeolithic Charcoal Records: Conclusions

Microscopic charcoal can rarely be linked to a specific species or source. Therefore, the origin of the fire cannot be reliably determined and is open to a range of different interpretations (Patterson *et al* 1987). In summary, there appears to be evidence to both support and reject the natural and human interpretations of the fire history in the Windermere Interstadial. Such evidence signifies that a multi-causal explanation may be more relevant with a complex interaction of human and climatic fire contributing to the charcoal record. Even if some of the charcoal is derived from human activity or natural fires, soil erosion is likely to account for a high proportion of the charcoal during cold Stadial-like periods. This would account for the pattern in the data whereby peaks in charcoal appear to be associated with inorganic sediments and low tree pollen percentages. Such an association would also lessen the impact of Upper Palaeolithic cultures. More proof is undoubtedly need from this period of the Pleistocene as it is notoriously hard to detect human/environmental impact within a semi or treeless landscape. At present it seems premature to infer a human fire cause for vegetation changes in the late-glacial with its different and perhaps fluctuating climatic conditions. Reasonably fine resolution (<1 cm) analyses are required to detect human activity in the early Mesolithic woodland environment, so interpretation of coarse resolution pollen and charcoal data prior to this should be treated with caution. As charcoal has been shown to have an affinity with sand particles, it seems necessary in future to develop a different method for detecting human activity in the Upper Palaeolithic, as charcoal studies alone appear to be insufficient.

10.3 Results from the Pre-Boreal c. 11,550-11,050 cal yr BP

10.3.1 The late-glacial/Holocene transition and early post-glacial environment

Recent revision and extension of the radiocarbon calibration curve (Spurk *et al* 1998; Kromer and Spurk 1998) has allowed the date of the late-glacial/Holocene transition to be calculated with more precision. The transition seems to be reflected by a doubling of the pine tree ring width at 11,530±20 cal BP (Björck *et al* 1996; Spurk *et al* 1998), with a potential error of only ±20 years (Kromer and Spurk 1998). Very similar dates, ranging from 11,500-11,650 cal BP, have also been obtained from other sources such as the Greenland ice cores and varved sediments from several European lakes (Johnsen *et al* 1992; Alley *et al* 1993; Taylor *et al* 1993; Björck *et al* 1996; Brauer *et al* 1999). In all cases the warming appears to have occurred over a period of a few decades (Dansgaard *et al* 1989; Johnsen *et al* 1992; Brauer *et al* 1999) and seems to have been synchronous across the North Atlantic region (Björck *et al* 1996).

Less than 50 calendar years after this transition, temperatures rose by approximately 10°C, resulting in a dramatic change to the environment and vegetation. The development of full woodland cover was delayed by about 300-400 years, possibly due to delayed migration of suitable species (Bennett 1986; Birks 1989). *"The exceptionally warm summer and winter temperatures, and the extended growing season, must have provided optimal conditions for the development of rich growths of grasses, dwarf shrubs and other low growing plants, which would have provided ideal grazing conditions for open country species such as reindeer and horse"* (Mellars and Dark 1998:237). In actual fact the delay in woodland establishment can probably be estimated as nearer 500 calendar years due to the revised radiocarbon chronology. The environment therefore provided a population-rich flora and fauna for almost half a millennium.

10.3.2 Pre-Boreal Human occupation of the Vale of Pickering

In England and France the presence of pre-Boreal human groups is generally recognised by the sporadic finds of 'long blade' lithic industries. These long blade industries were potentially closely related as the sea level during the same period was still very low and England was still joined to the continent via an extensive land bridge, although sea levels were rising rapidly (Figure 3.11). Despite the ease of access from the continent, there is surprisingly little evidence for human occupation of the Vale during the pre-Boreal (Conneller 2000a,b). In her thesis Conneller classes the lithics from Site L, Site K and Flixton 2 (Figure 10.1) as being deposited by pre-Boreal human groups. She believes the lithic scatters were deposited during short excursions to the Vale sometime before the arrival of the Magdelanian hunter-gatherers who occupied Star Carr. Once again these Pre-boreal visitors brought their own provisions of flint with them as they were unsure of the environment that they would encounter but they also utilized local supplies of flint as well. This time the visitors were in no great hurry, as some of the blades would have taken some time to prepare and knap. For example, Flixton 2 "*Would appear to reflect a butchery episode of at least three horses*" (Mellars and Dark 1998:238). The visitors probably came from the continent as well as from an area to the south, as the Vale of Pickering lies on the north-eastern limit of long blade activity in England (Conneller 2000a,b).

10.3.3 Pre-Boreal Human Impact

During the Pre-boreal there is evidence to suggest that fires occurred within the catchment. For instance, the regional charcoal curve (Profile D), registers a charcoal peak during zone D-4b, although the charcoal levels are still much lower than those attained during the previous late-glacial (zone D-4a). Pre-boreal charcoal deposition is also observable in zone S-4 of Day's 1996 profile (Day 1996a). It is assumed that these fires relate to the flint and faunal scatters discussed in the previous section.

In terms of the lake-edge profiles, only 3 sediment cores show evidence for charcoal deposition during the Pre-boreal, primarily because most sediment deposition commences at the beginning of the early Mesolithic. At Barry's Island, in profile LAP,

charcoal levels rise towards the top of zone LAP-4, which is probably equivalent to the Pre-boreal. Nevertheless, the charcoal levels are still lower than those attained during the Late-glacial. Significantly, there are no signs of Pre-Boreal human occupation from the island, although occupation along the nearby lake edge to the south and east cannot be ruled out. To the south of No Name Hill in profile NM there is a very sharp and temporally discrete peak in charcoal concentrations at the very bottom of the profile. This may be attributable to Pre-boreal fires on nearby Flixton Island (see previous section), but could also be explicable by an association of charcoal with sand particles (Nichols *et al* 1997). Finally, at Flixton School Field in zone FS-5a there are a number of quite significant peaks in charcoal, which may suggest more than one episode of fire occurrence. However, the dating of the deposits is problematic, and the fires are more than likely to have occurred during the very earliest Mesolithic.

It is impossible to assess whether there was any human disturbance to the vegetation associated with these fires, because of the rapidly changing nature of the vegetation and environment. There is also generally a much lower sample resolution during these episodes.

10.4 Results from the early Mesolithic for the period c. 11,165-10,190 cal yr BP

10.4.1 The early Mesolithic environment

At the beginning of the early Mesolithic, the summers were hot and dry and winters were cold (Tallantire 1992). The vegetation history follows the same broad regional pattern described by (Day 1996a; Beckett 1981). That is, the climate and vegetation in the Vale was changing rapidly from an open periglacial landscape of grasses and shrubs to open juniper and then birch and poplar woodland with an understorey of ferns and grasses. On dry land, birch woodland had already started to develop by c.10,275±175 ^{14}C yr BP at Flixton Island (AK87, Simmons *et al* submitted) and by c. 10,140±100 ^{14}C yr BP at Barry's Island (LAP). By 9700 ^{14}C yr BP open birch woodland with an understorey of *Dryopteris filix-mas* was fully established.

Willow would also have formed a narrow band of vegetation along the waters edge, although the actual extent appears to have been more extensive in some places than in others time e.g. willow was more prolific at Star Carr. This variation in its local importance was dependant upon specific local conditions such as the depth of water at a specific time period and inter-specific competition. Aspen was also a significant component of the vegetation at the waters edge ($\geq 1\%$ TLP&S), although it seems to have been more important along the western and northwestern sides of the lake than along the southern and eastern sides. In some cases this could be explicable by poor levels of preservation and lack of experience in identification. Nonetheless, low levels of aspen pollen identified from sediments at Flixton School and profile D, probably attest to its presence at least in low levels, throughout much of the catchment near the lake-edge.

For the first couple of hundred years the soils continued to be unstable and the ground flora remained diverse, as indicated by the continual presence of ruderals e.g. *Artemisia*. The stony substrate of mixed glacial deposits would have provided a thin covering of soil and the steep slopes along the lake edges would have increased the likelihood of soil movement. Localised inwash events and mineral based hill-wash is best developed off the shores of steep-sided islands e.g. at No Name Hill profile NAQ. The resulting areas of continually disturbed ground allowed the annual germination of ruderals. Constant trampling by wild animals along semi-permanent track ways or at watering areas and digging over by wild boars is also a probability. Wind throw gaps, natural tree wastage, beaver activity, ring barking of trees by animals and infrequent natural fires would also contribute to the continuation of the dynamic vegetation mosaics.

The development of the lake vegetation was rapid, with any areas of inorganic substrate becoming quickly colonised by bullrush. On the drier margins, marsh fern was the local dominant but once an organic substrate had become established, reed and sedge beds extended rapidly into the open water. Soon the extent of the open

water had diminished as a thick band of vegetation flourished between the willow carr and the deeper, open water. At Star Carr, beds of *Phragmites* (common reed) formed the dominant type of reedswamp vegetation, but towards the southern edge of the lake Cyperaceae (sedges) became more prevalent e.g. at Flixton School. This is presumably due to the pH of the substratum, which becomes more alkaline towards the southern edges of the Vale. The depth of the water and fluctuations in the water depth would also have been significant (>1 m). Cyperaceae is more tolerant of large lake level fluctuations than *Phragmites,* suggesting that the outflow of the lake near to Star Carr was fairly constant during the early Mesolithic.

By c. 9650 ^{14}C yr BP (c. 10,920 cal BP) Lake Flixton provided a very stable environment for humans and wildlife, above what was probably the hydrologically unstable reaches of the River Derwent (Schadla-Hall *pers com*). Even so, in some areas of the lake, the lake level still fluctuated, possibly annually (dependant on water depth). Periods of rising and lowering of the water table are shown by variations in the stratigraphy and by fluctuating numbers of pollen from aquatic plants and microscopic *Pediastrum* algae.

Towards the end of the early Mesolithic there is an important transition from open birch woodland to dense hazel woodland. Hazel pollen first becomes consistently present in lake edge deposits dated to just after c. 9385±85 ^{14}C yr BP and then increases rapidly at 8940±90 ^{14}C yr BP (Day and Mellars 1994). These dates can be calibrated to 10,430 cal BP and c. 10,170 cal BP, respectively (Dark 2000). Most of the birch woodland is replaced by hazel, whilst in the west and south of the lake e.g. any remaining birch is often replaced with pine. The sheer quantity of hazel and dense canopy of the woodland causes a reduction in the species' diversity of the vegetation around the lake.

These separate immigrations of first *Betula*, then *Dryopteris filix-mas* and finally *Corylus* appear to be broadly synchronous throughout the Vale and as such can be

considered to provide important markers for correlating periods of vegetation disturbance or fire activity in the absence of secure radiocarbon dates.

10.4.2 Early Mesolithic Human occupation of the eastern Vale of Pickering

There are numerous early Mesolithic sites around the periphery of the lake and upon the lake islands (Figure 10.2). The sites were occupied over various time spans, forming a wide variety of sites in terms of nature, location and use. These early Mesolithic sites mainly occur during the period of dense birch woodland cover, at or after 9700 ^{14}C yr BP (< c. 11,165 cal yr BP).

According to Conneller (2000a,b) the lithic scatters show that during the early Mesolithic the occupants of the Vale were familiar with their environment. There is evidence that they often knapped flints at one site and then took the prepared lithics with them to another site, as detected at Barry's Island. At some sites they left their tools behind after they had gone to a specific area to do a specific task (e.g. the north side of No Name Hill). At certain times and places the inhabitants even left behind caches of flints, to return to at a later date e.g. at Flixton School and Seamer Carr. At Flixton School these flints had already tested or partly used, suggesting that the hunter-gatherers were very sure of their environment and intended to return to the area once more or even on a regular basis (Conneller 2000a,b).

10.4.3 Early Mesolithic Human Impact Studies

Throughout most of the early Mesolithic and pre-Boreal, charcoal is found at varying concentrations, even in the center of the lake approximately 800 m away from the nearest shoreline (profile D, Chapter Three). A great deal of this charcoal is thought to be background deposition attributable to the early Mesolithic occupants of the Vale.

The regional charcoal curve (Profile D, Chapter Three) indicates periods of increased fire activity within the region and can be used for comparison with the archaeologically linked profiles. Approximately 3-4 distinct periods of fire activity can be detected in Profile D during the early Mesolithic alone (Figure 3.5, Chapter Three).

This can be compared to the two phases detected at Star Carr (Day 1993) and the three phases observed from Clark's site (Mellars and Dark 1998), as well as the various phases of fire activity discussed in the preceding chapters.

The following sections clarify the conclusions that have been reached about the early Mesolithic occupation around the lake system.

10.4.3.1 Location
The location of Lake Flixton provided access to a wide range of environments and resources i.e. a productive wetland, the coast, the Yorkshire Wolds and the North York Moors. It was probably a good hunting location, with a wide range of fauna to choose from, as the lake would have provided a predictable area where animals would congregate. Access in and around the lake and open woodland was also good, with good visibility around the lake system and surrounding area.

Human settlement and disturbance of the vegetation occurs on the islands and along the periphery of the lake system. The distribution of archaeological evidence and information from the pollen profiles suggest that occupation took place within a limited zone at the lake edge, between approximately 24.5-25.5 m OD. The reason why these archaeological scatters are concentrated within such a narrow zone is currently unknown. Perhaps this zone was seasonally dry in the summer? Soil from Trench A at Star Carr provides evidence for standing water and seasonal flooding (Mellars and Dark 1998:82), which in turn suggests that the lake level was seasonally variable. Conversely, Mellars and Dark (1998:239) suggest that, *"It was probably the closing in of the dense birch woodlands around 9700 BP which forced the human groups to concentrate around the edges of lakes and rivers, where the waterside vegetation would have provided much richer grazing for the animal populations than that available in the closed canopy woodlands"*.

There was also a tendency for occupation upon promontories, in areas where the land rapidly slopes off, and where there was easy access to deep and open water. Most areas of the lake system were occupied at some point during the early Mesolithic,

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although some areas perhaps more fleetingly than others (see Figure 10.2). It is suggested that only areas with poorly drained soils were avoided at all costs. The location of springs and freshwater streams also appears to have influenced the location of human settlements (Lane 1998).

10.4.3.2 The Nature of Human-related Vegetation Change

The nature of the vegetation disturbances are hard to define and attribute to a specific cause because the number and nature of the occupation phases probably varied considerably over short time-spans, producing a composite reaction within the vegetation. However, during the first half of the early Mesolithic, the nature of all the vegetation disturbances appears to be very subtle but similar.

During FS pre-Phase 1, FS Phase 1, NAQ Phase 1 and NAZ Phase 1, statistical analyses have shown that pollen from birch and willow tended to increase or fluctuate very slightly, coinciding with significant and sometimes considerable fluctuations in the production of male fern spores (e.g. at No Name Hill, NAQ). The occupation by human groups also coincided with periods when the reedswamp was burnt. This resulted in peaks or declines in sedges and grass pollen and the generation of charcoal from reeds or rushes.

At both sites there is also a small increase in pollen from heliophytic trees and shrubs and herbs indicative of disturbed habitats. Shrubs such as Rowan, Elder and Blackthorn appear sporadically and during Phase 1a at NAQ, even *Fagus* pollen is visible. Ground disturbance is suggested by *Artemisia, Silene* and an increase in nettles (especially at Flixton School). These changes are not statistically testable and may be an artefact of the sampling interval, but such changes do seem viable considering there is disturbance to the understorey of ferns and an increase in erosional inputs (shown by inorganic particles or *Zygnema* algae). All the preceding periods of human occupation occurred ≤c. 9700 but ≥ c. 9400 ^{14}C yr BP.

Later in the early Mesolithic but before the arrival of hazel, i.e. > c. 9400 ^{14}C yr BP, there is another phase of human activity on No Name Hill (NAQ and NAZ, Phase 2). This time, the pollen changes are extra-local (>30 m away), and probably occurred along the western or eastern edges of the island. In spite of this, the disturbance was intensive enough to cause a decline in grass pollen, and fluctuations in sedges and ferns.

Towards the end of the early Mesolithic c. 9220±100 ^{14}C yr BP, during Phase 2 at Flixton School Field, a section of fine resolution analyses highlights a period with relatively high charcoal deposition. The fluctuations in the various pollen curves along with the presence of microscopic charcoal, imply possible manipulation of the woodland and lake edge by human groups. The saw-toothed fluctuations in Cyperaceae pollen may also be attributable to the actions of hunter-gatherers as there appears to be a slight relationship between charcoal and Cyperaceae levels (including high proportions of *Cladium mariscus*). This period of vegetation disturbance is dated to between c. 9220±100-9030±60 ^{14}C yr BP and appears visible because the sedge swamp is *in situ*. Consequently the human activity along the dry land edge is much nearer to the pollen profile.

Both phases of vegetation disturbance at Flixton School are apparently intense enough to cause an increase in soil erosion. Similar events occurred at Star Carr, and very slight changes in erosion are also visible at NAQ during Phase 1.

10.4.3.3 The processes responsible for the pollen changes
Disturbance of Male Ferns
During Phase 1 at Flixton School Field and No Name Hill (NAQ), any detrimental affects on the abundance of male fern spores are thought to be caused by trampling, which results in temporary and/or permanent damage to the stands (see Chapter Eight). Conversely, any increases in the abundance of fern spores may be attributable to the expansion of fern stands, into areas of newly created bare soil. Other processes

such as grazing by deer, (e.g. Bennett *et al* 1992), utilization for food (tubers) or harvesting of the ferns for bedding could also have taken place.

Disturbance of the woodland

Microwear analysis of the lithics from Star Carr (Dumont 1988, 1989) has demonstrated that the people at Star Carr were able to cut down birch, poplar and willow trees fairly easily. They also extracted birch resin for use in cakes and to act as a glue (Aveling and Heron 1998). In contrast, in the sites examined in this thesis there is no identifiable and consistent evidence to demonstrate that the occupants were cutting down (or coppicing) large areas of tree cover as might have occurred at Star Carr (Day 1993). In fact there appears to have been a very limited amount of tree removal, if any at all.

The lack of tree removal can probably be explained by the open nature of the birch woodlands. The openness of the woodland and floral diversity meant that there was no need to clear the trees. Trees would provide additional shelter and dead wood is also likely to have been abundant, so it was not necessary to cut down many additional trees for fire wood or to make tools. Neither did these very early Mesolithic settlers seem to be taking advantage of breaks in the tree cover as suggested by some authors (e.g. Brown 1997), as the location of settlement seems to be determined more by socio-economic or environmental factors (see p281).

Perhaps then, with the exception of Star Carr, the birch woodland was not an important part of the economy at any of the sites studied in this thesis; or perhaps in most areas of the Vale of Pickering, as in the Oban area, *"anthropogenic management of woodlands during this period was on a scale too small to be recognized from palynological data"* (Macklin *et al* 2000:113). Clearance of just the occasional tree is unlikely to leave its mark in the pollen record, as pollen reductions from isolated individuals would be drowned out by pollen production from surrounding trees. Even if there were an element of woodland management, unless it was large scale and

occurred within a few meters of the sampling site, it would probably produce a composite reaction within the pollen record.

Göransson (1986) has proposed a model of forest utilization that allowed for the role of Mesolithic hunter-gatherers in forest management. In the pre-Neolithic, foragers generated coppice and girdled woodland by ring-barking, thus creating browse for animals and assisting shrubs and grasses to flourish under a more open canopy. Such practices should produce no change to the pollen rain and would be indistinguishable from virgin forest. Consequently there is a need to date the piece of coppiced Salicaceae wood which was identified from early Mesolithic layers at No Name Hill (trench NAZ). If the wood were to be successfully dated to the early Mesolithic, it would provide preliminary evidence to support Göransson's model, as there is little observable pollen evidence to support woodland manipulation at No Name Hill.

The small peaks in birch pollen that are observable at Flixton School and No Name Hill probably result from increased flowering due to a decline in the surrounding plants, e.g. grasses at the sampling site. Birch might also have been favoured by the reedswamp fires, resulting in an increase in seedling expansion into the open areas. However, as birch trees do not produce pollen until they are 5—10 years old, most of the visible pollen must have come from mature trees (Grime *et al* 1991).

The small increases in woodland shrub pollen (if genuine), may denote small and ephemeral canopy openings, perhaps with some soil disturbance at the woodland edge which allowed an expansion of grasses and almost certainly provided areas for the expansion of male fern or at least allowed an increase in the number of spores reaching the ground. Any increases in grasses and ferns may also be the result of coppicing practices, as coppicing is said to result in an increase in flowering (Göransson 1986).

Burning of the reedswamp

At both sites, most of the vegetation disturbance appears to have been at the lake edge. The microscopic charcoal examined here, and the macroscopic charcoal data obtained by Day and Mellars (1994) and Dark (1998), demonstrate that burning of the reedswamp occurred on more than one occasion at more than one location within the Vale of Pickering. At No Name Hill and Flixton School especially, reedswamp burning was repeated, as shown by repeated finds of *Neurospora*, reed and rush charcoal. Unfortunately, it is not possible to determine the exact fire regime at each site due to taphonomic factors (Clark 1988a). In reality, fires may not have occurred all that frequently, as the resolution of fire events is only as good as the sample resolution of the study.

At the sites studied in this thesis, reed and particularly rush, seem to have been burnt most frequently, although not all of the charcoal will have originated from burning of the reedswamp. Sedges also appear have been affected by the burning episodes, particularly at Flixton School (Phase 2). However as there is no direct evidence to substantiate this (e.g. species-specific charcoal), the fluctuations in sedge pollen may just be coincidental. An influx of inorganic particles associated with human occupation may have provided the right conditions for the sedges to flourish and produced a swamping of the pollen spectra.

Day (1993) suggests that charcoal changes can be directly related to changes in the vegetation at Star Carr. At No Name Hill and Flixton School (in Phase 1 at least), sedges and grasses also seem to decline with the occurrence of charcoal peaks and therefore may also be directly linked to charcoal production. Unfortunately it is impossible to establish the impact on rush communities as rush pollen is never preserved in a fossilised form (Andrew 1984), and is therefore effectively 'invisible' in the palaeoecological record. It may actually have been an important factor in the lake ecosystem during the Mesolithic.

Juncus effusus (Soft rush) is the commonest rush and has a broad habitat tolerance and widespread occurrence. It is often one of the first plants to become established on bare soil due to its large seed bank and is usually established in areas which are above water level for part of the year, i.e. *Juncus effusus* occurs at the very edges of lakes, often on base rich soils where disturbance or fluctuating water levels expose large tracts of bare soil (Grime *et al* 1991).

The ecology of *J. effusus* may provide the explanation for its continual occurrence in the charcoal record, especially as soil from Trench A at Star Carr supports possible evidence for standing water and seasonal flooding (Mellars and Dark 1998:82). *Juncus effusus "is frequent in grazed habitats, where it tends to be avoided by sheep or cattle, and is moderately tolerant of annual cutting and trampling"* (Grime *et al* 1991:148). If the lake edge was an important grazing habitat for wild animals, then over a period of years stands of rush might expand and gradually diminish the grazing potential of the wetland. In order to maintain the lake edge as an attractive grazing location, early Mesolithic peoples might have occasionally burnt the wetland (especially rush).

The lack of correlation between the charcoal curve and other species e.g. birch and hazel in Phase 2 at Flixton School, and birch and ferns at No Name Hill Phase 1 and 2, may also suggest a domestic origin for some of the charcoal. In addition, the taphonomic pathway of charcoal is probably very different from pollen. Unless the fires occur locally and the charcoal remains *in situ* the charcoal may be deposited a number of years after the fire event (Whitlock and Millspaugh 1996). This would then account for the lack of correlation between the pollen diagrams and the charcoal data.

10.4.3.4 Chronology and Duration of Occupation

There is evidence to suggest that human occupation occurs at various sites around the lake, before, during and after the occupations at Star Carr (Profile D; Lane 1998). Unfortunately precise dating of the potential occupation events is often problematic due to a radiocarbon plateau at 9600 ^{14}C yr BP (Mellars 1990) and a lack of reliable dates (caused by lack of datable terrestrial material).

It is hypothesized that due to the similarities in the male fern curves between the different sites, the rise in *Dryopteris filix-mas* can be used as a local chronological marker. A similar assumption has been made about the *Corylus* rise (Dark 1998). Dark (1998) has been able to absolutely date the occupations at Star Carr by 'wiggle matching' a number of closely spaced radiocarbon dates with the radiocarbon curve of Struiver *et al* (1998). By comparing the male fern curve between sites, it will then be possible to produce approximate but 'absolute' dates for the undated phases of occupation within this thesis (see Figure 10.3 and Table 10.1).

Flixton School

Comparison of the male fern curve, would then place the occupation phase at Flixton School Field (Phase 1, 303.5-299 cm), just before the initial settlement phase at Star Carr (see Figure 8.13). FS Phase 1 must then have occurred before c. 9650 ^{14}C yr BP or >10, 920 cal yr BP, using dates from Day and Mellars (1994); Dark (1998) and Dark (2000). The same approach has been used to date pre-Phase 1 at Flixton School. If FS Pre-Phase 1 is considered to be part of Phase 1, then this pushes back the start date to c. 11,000 cal yr BP.

If the shape of the charcoal concentration curve or the Charcoal:pollen ratio curve can be used as a reliable indicator of the duration of occupation, then Phase 1 at Flixton School is estimated to have lasted over a period of c. 160-225 uncal years, with occupation varying greatly in intensity over that time, and consisting of 4 minor-phases of occupation. Each minor phase of occupation lasts for c. 50-60 years. This compares well with the 75-100 year occupation phases recorded for Saami occupation in Finnish Lapland (Hicks 1993).

No Name Hill

At No Name Hill, a piece of antler from a butchered red deer has been dated from sediments that correlate to just before the clay inwash band at NAQ and NAZ. This dates the beginning of the fine resolution sampling period at NAQ (Phase 1) to just

after 9510±60 ^{14}C yr BP (<c. 10,740 cal BP). This places it sometime after the initial occupation at Star Carr but just at the start of the second phase (Day and Mellars 1994; 1998; Dark 2000). As the charcoal concentrations are consistently high throughout this fine resolution phase and beyond, this suggests that there was continuous activity over a very long period, perhaps c. 108 uncal yr. The charcoal deposited in Phase 1 at NAZ is also thought to relate to this occupation, whereas no fires occurred along the south of the island at this time.

All Profiles

After most phases of local fire activity, charcoal levels still remain higher than background levels (i.e. > c. 150 x 10-5 $cm^2 cm^{-3}$), despite being greatly depleted. This suggests that fire activity may have carried on elsewhere within the catchment e.g. Phase 2 at No Name Hill probably occurred somewhere upon the island around 9320 ^{14}C yr BP. Although the regional profile (Chapter Three) indicates 3-4 different phases of early Mesolithic fire activity, it is possible that there were no gaps in the human occupation of the lake system during the whole of the early Mesolithic, although the main foci of activity may have moved.

The general conclusion from the pollen and charcoal curves is that the phases of occupation generally lasted for decades rather than months or years, although that is not to say that some sites were not just visited very briefly. It also appears that the intensity or position of the fire events may have varied greatly within any one period of occupation, resulting in a multi-peaked charcoal curve. This could also indicate short periods of abandonment within a longer phase of occupation. However, work on charcoal taphonomy (Whitlock and Millspaugh 1996, Clark 1988a, Nichols *et al* 2000) suggests that it might be premature to conclude too much from the microscopic charcoal curves alone.

Table 10.1 summaries the chronology and duration of the different occupations in relation to Star Carr.

Table 10.1   **An Estimated Chronology of Occupation for the time period 10,000-9,000 ^{14}C yr BP (11,165-10,190 cal yr BP)**

Location	Occupation Starts Direct Calibrated Age (no sigma error shown)	Occupation ends Direct Calibrated Age (no sigma error shown)	Duration
FS Pre-Phase 1*	Potentially c. 11,000 cal BP	Continues as FS Phase 1	c. 50-60 uncal years
FS Phase 1*	Possibly before 10,920 cal BP	c. 10,760 cal BP	c.160-225 uncal yr (accum rate)
Star Carr Phase A	10,920 cal BP	10,840 cal BP	80 cal yr
Star Carr Phase B	10,740 cal BP	10,610 cal BP.	130 cal yr
NAQ/NAZ Phase 1*	approx. 10,740 cal BP	c.10,630 cal BP	c. 108 uncal yr
NAQ/NAZ Phase 2	approx. 10,525 cal BP (c. 9320 ^{14}C yr BP)	Uncertain	?
FS Phase 2	10, 326 cal BP (9220±100 ^{14}C yr BP)	10,211 cal BP (≥9030±60 ^{14}C yr BP)	c. 115 cal yr (c. 60-105 uncal yr)

* By correlation with *Dryopteris filix-mas* curve and absolute chronology (Dark 2000)

10.4.3.5 Intensity of occupation/spatial distance from source

Even though the pollen profiles were located <30 m from the archaeological 'sites', it seems that the human impact on the vegetation was never very intensive. The effect on the vegetation of these periods of occupation appears to have been very subtle, especially in comparison to Star Carr. At Flixton School Field in zone FS-5, a time almost contemporary with the first phase of occupation at Star Carr, very little change to the woodland occurred, although disturbance of male fern stands was marked and small changes to the reedswamp occurred. At Star Carr by comparison, there are very sharp changes to the birch, grass and fern curves (Day 1993). This might suggest that most interference with the vegetation was very localised or that there was a lower intensity of impact in all the other early Mesolithic sites except Star Carr. In all probability, larger areas of reedswamp and woodland were affected by the activities of human groups at Star Carr than elsewhere. This may be due to the size and/or nature of the settlement site, as the concentration and extent of finds are generally higher at Star Carr than elsewhere.

Conversely, this could also be attributed to the spatial location of the core in relation to the disturbance, and differences in the pollen source area. The former is dependant on the location of the profile at the lake edge. Profile M1 (Dark 1998) is 10 m away from the shoreline during the first phase of human activity whereas profiles taken from No Name Hill and Flixton School Field were required to be taken nearly 30 m from the lake edge due to constraints of preservation. This places them near to the limit of the detection of disturbance (see Edwards 1982). It is not until the second disturbance phase at Flixton School (Phase 2), that the vegetation disturbance appears to be more intense (although it has not been possible to test this statistically). This is because the focus of activity has now moved closer to the profile, due to the encroachment of the lake edge.

The palynological signal of a disturbance phase is therefore dependant on the location of the core relative to the disturbance site at a specific point in time. The identification of a phase of vegetation disturbance that is not intercalated with archaeological material can then be considered to be somewhat 'fortuitous'. The intensity of the changes in the vegetation at Phase 1 Flixton School and No Name Hill, could well be a factor of pollen filtration by the canopy, depending on the location of the disturbance (see Table 10.2 for a summary of factors affecting the apparent 'intensity' of an occupation phase).

It seems clear that fires within the marginal vegetation, and especially within the reed and rush beds, were fairly widespread in time and space. In contrast, there is little evidence for burning of the dry land except the occasional piece of microscopic charcoal that may be derived from domestic fires. The results of this thesis are therefore consistent with the findings from Star Carr as Mellars and Dark (1998:172) concluded that, *"In the post-glacial period [early Mesolithic].....all significant charcoal abundances can be linked with burning of swamp communities, and there is no evidence for major woodland fires"*.

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Comparison of regional and lake-edge charcoal curves shows that the microscopic charcoal curve predominantly reflects fires within a few hundred metres of the sampling point. In fact the majority of the charcoal is likely to have travelled only tens of metres. This is demonstrated by the sharp, quasi-exponential decline in charcoal between NAZ and NAQ at No Name Hill (Chapter Seven), and the difference between the charcoal profiles at Day's site M1 and Clark's site at Star Carr, which is a distance of just 30 m (Mellars and Dark 1998). Day (1996a) explains this by suggesting that the lake reeds burnt very rapidly, releasing little energy and consequently the charcoal was deposited within 10s of meters. Most of the charcoal is unlikely to have traveled more then 250 m and definitely less than 500 m, as there is an absence of charcoal at NM, just 250 m to the south of NAZ at No Name Hill (Chapters Four to Seven). At NM there is also no indication of the early Mesolithic occupation at nearby Flixton Island. This suggests a very localised deposition of charcoal during fire events (<250-500 m), with fires confined to areas fairly close to habitation/activity sites.

10.4.3.6 Repeated Occupation – 'A persistent place in the landscape'

One reoccurring finding is that the hunter-gatherers were returning to the same place time and time again. For instance, at NAQ burning occurred at just after 9510±50, c.9320, c. 9075 and sometime after 8900 ^{14}C yr BP. At Waun Fignen Felen, Barton *et al* (1995:109) also note that "*..One of the key features of this upland site is that it was repeatedly visited*", even though these visits were generally of a short duration. Perhaps then, this was a widespread phenomenon which occurred for any number of social, environmental or social and environmental reasons, (e.g. The Mitassini Cree of the Mackenzie basin in north-west Canada, regularly re-visited specific locations for specific reasons (Tanner 1979)). Such reasons may include: favourite hunting or gathering areas; preference for secondary woodland; a reliable supply of running water; or good shelter. Repetitive use of a single site is one of the criteria of Schlanger (1992:97), to describe a 'persistent place in the landscape'.

10.4.4 The cause of early Mesolithic fires

The following sections discuss the cause of the fires in the early Mesolithic and any potential strategies that may have been linked to them. This discussion is also the subject of a paper by the author (Cummins 2000c).

10.4.4.1 Reedswamp fires: The accidental spread of fires?

The charcoal and pollen records analysed from No Name Hill and Flixton School infer that during the early Mesolithic, vegetation disturbance entailed accidental and/or deliberate burning of the vegetation in a limited zone at the margins of the lake.

Repeated burning of the reedswamp may be explicable by the accidental spread of fire from hearths or by the occurrence of natural fires. The spread of fire to the swamp communities could have occurred during dry hot summers and need not have occurred too frequently as much of the charcoal would be derived from the continual presence of cooking or hearth fires. During the early Holocene, seasonal variations in temperature were much greater than at present (Huntley 1993) creating dry conditions in the summer months. The large peaks in microscopic charcoal would then be explicable by the almost persistent presence of domestic fires, which occasionally spread to the surrounding lake edge margins.

On the other hand, the charcoal data suggest repeated burning of the swamp at several localities and this is hard to explain, as one would expect the Mesolithic occupants to learn from mistakes and try to minimize disturbance to their environment. Maybe, what started off as an accidental fire may have proved beneficial in the long term and was then encouraged or copied? As Law (1998) states, *"Even if natural wetland fires were frequent in Mesolithic Britain, it is unlikely that one particular location would have been set alight so regularly"* (In Mellars and Dark 1998:201).

10.4.4.2 Or an Economic Strategy?

Actual deliberate burning of the environment suggests an economic strategy that must have proved beneficial to the hunter-gatherers, e.g. an aid to hunting or plant

collection, or an increase in availability of raw materials. Enough is known to make some broad generalizations about the use of burning, although the paucity of deciduous fire data means that the best parallels are from New England and the Appalachians. After talking to the elders of North American Indians, Lewis (1982:65) concluded that Indians had a sophisticated knowledge of fire effects and uses, and that they burned *"to manipulate and eventually to create local environments of their own design"*. For example in northern New England mires were burnt over at the edges to increase quantities of birch and aspen which are the principal food of beavers. A beaver's tail is an excellent source of fat, which is essential for human survival during the winter months. There is little evidence to support any increase in birch or aspen anywhere other than Star Carr, but fires were also used for other purposes.

Hunter-gatherer groups would have concentrated on the productive environments around the lake as, *"An economic imperative would have been to maintain key inland resource centres in their most productive successional state"* (Simmons and Innes 1987:397-8). Hydroseral succession to carr, would be prevented by light, shallow burns, confined to small patches and rotated every 5-10 years (Law 1998). By firing various parts of the lake at different times it would be possible to keep the lakeside vegetation in various states of succession and provide reliable plant food for the human groups as well as preventing carr formation. This would also explain the repeated use of areas during the early Mesolithic

Burning of reed/sedge beds, also increases the shoot biomass of the area, if burning is undertaken in the spring or late autumn (Thompson and Shay 1985). Thus firing the lake edges would also provide browse for wild animals and produce predictable hunting areas as herds are attracted to newly-burned areas from an extensive area (Spencer and Hakala 1964; Ball *et al* 2000).

After burning, maximum nutrients would be available in the first and second season after the burn, with maximum growth of herbs expected in the 3-4th years (Mellars 1976). Finally after 15-20 years there would be no more benefit and the human groups

would need to re-burn the same area. More importantly, they would only need to burn small areas of land, perhaps less than 1/10th of the whole area, interspersed with undisturbed areas. Consequently, the resultant small and composite disturbance to the pollen rain would be hard to detect in pollen diagrams (Jacobi *et al* 1976:317). If burning the lake edge was attributable to a hunting strategy one would not expect the archaeological deposits to indicate long-term occupation of the area but, to exhibit traits associated with a predominantly hunting based site. At present this type of information is still being gathered from the lithic and bone data within the Vale. It is possible that all sites other than Star Carr fall into this category.

Alternatively, burning the lake edge may be attributable to a food production strategy, as a very early precursor to agriculture. The seeds of all Cyperaceae are edible (G. Hillman *pers com.*) and most other wetland plants are also very good sources of carbohydrate and protein, e.g. *Typha* and fern rhizomes. Procurement of a regular supply of carbohydrate would have been very important to hunter-gatherers and so, *"irrespective of the relative energy costs of its procurement, plant food must have been a major component of the Mesolithic diet"* (Zvelebil 1994:59). This view is endorsed by many other authors, e.g. Speth (1989; 1990; 1991), who stresses the importance of carbohydrates and vitamins within a diet and not too much protein. Due to the heavy and bulky nature of plant resources, plants could often have had the most influence on the location of long-term occupation sites or base camps. It is often the distribution of plant resources, whatever their contribution to the diet, that determines the environmental (rather than social) location of the larger and or longer-term occupations sites (Spikins 1999). Thus if any of the Vale of Pickering sites were base camps, as has been suggested for Seamer Carr (Utchiyama 1996), then it is likely to be related to the exploitation of plant resources. This may also explain the (possible) widespread management of the wetland vegetation.

The reedswamp may have also have been burnt during a hunting event because, where large reedbeds are adjacent to woodland they will attract deer (Hawke and Jose 1995). Perhaps then, the charcoal originates from fires used to drive herds into the lake,

where they could be easily killed by hunters waiting in boats. As *"..in the absence of horses, hounds and firearms, the most successful methods of hunting red deer, roe deer and elk appear to be by a drive [into a lake] or from a blind"* (Andresen *et al* 1981:42). This is due to the animals keen sense of smell and hearing.

Hunting activities alone or perhaps in association with food and resource production may provide the reason for manipulation of the lake edges. Sedges could be used for basket weaving, bedding, fodder, thatching and housing as seen from the Mesolithic in southern Sweden (Regnéll *et al* 1995) and the Dinka pastoralists from the Sudan (cited in Mellars and Dark 1998:224, see Figure 10.4). To manage reeds for cutting or thatching, the reedswamp is burnt once or twice in the first 1-2 years and then not again for 50-80 years (Law 1998:201). This is comparable with the length of these minor-phases of occupation at Flixton School (according to the charcoal data).

Obviously there are lots of scenarios for what might have occurred. When such small areas are utilized and burnt it is hardly surprising when there is only a minor signal detectable in the pollen record. It may not be possible to really detect and unravel the type of processes and management involved, until the later Mesolithic, when people apparently had a larger impact on the environment (see later).

10.5 The Final-early Mesolithic <9000 ^{14}C yr BP (< 10,190 cal yr BP) to the Later Mesolithic

10.5.1 The Natural Environment

At the end of the early Mesolithic and the start of the later Mesolithic i.e.< c. 9000-8800 ^{14}C yr, England was still joined to the continent (Figure 3.11), although global sea levels were rising steadily. Consequently, the movement of people, plants, animals and ideas across the North Sea Basin was still possible. From c. 9000-8000 *^{14}C yr BP* the climate was drier as shown by lower palaeodischarge and palaeolake levels (Starkel 1984, 1991) and dry lake sediments (Tipping 1996). The climate was also

approaching the start of the Thermal Maximum, with temperatures c. 2°C higher than those of the present day.

From c. 9000 ^{14}C yr BP (c. 10, 190 cal yr BP) hazel was the dominant tree or shrub on the drier soils but from around 9000 ^{14}C yr BP (if not before), elm was also found in the woodland. Slightly later oak was also present although its establishment within the Vale is often delayed compared with the national picture (e.g. Huntley and Webb 1983, Birks 1989). The timing and degree of the rise in elm and oak appear to be asynchronous and dependent on the local conditions. The immigration of oak is particularly asynchronous, occurring much earlier in the east and south of the lake basin compared to the northwest e.g. at Seamer Carr (Cloutman 1988b). However, oak percentages are consistently low at most sites until the start of the alder rise.

At the transition from land to water, marsh fern was the chief colonist but reed and sedge beds also extended out into open water. As the lake hydrosere proceeded so the water level in the lake rose and the vegetation encroached further into the lake. The stratification of the lake sediments and the pollen and spore data both suggest that lake levels may have fluctuated at certain times during the later Mesolithic. Periods of higher or lower water table are shown by stratigraphic remains and the number of microscopic *Pediastrum* algae (see Section 11.4). These fluctuations provide a cause for some of the levels of poor pollen preservation at the lake margins e.g. NM zone-8.

Throughout the Boreal period charcoal is found at varying concentrations, even in the deepest sediments, hundreds of metres from the shore. Pollen from plants that colonize disturbed ground also turn up regularly, as does occasional evidence for catchment erosion.

During the Atlantic i.e. after c. 7500 ^{14}C yr BP, the main addition to the vegetation was alder. The timing and degree of the rise in alder also appears asynchronous, also dependent on local conditions (see Section 11.3). The expansion of alder carr, intermingled with some willow was often at the expense of pine and seems to have

occurred mostly along the lakeshores in between the drier woodland and swampy reed and sedge beds. Shallowing of the lake was widespread and a zone dominated by meadowsweet marks the transition to dry land. By 7640±85 ^{14}C yr BP Alder carr had already reached further than halfway between Flixton Island and Star Carr, and open water probably only existed in the very deepest parts of the lake, most notably in areas covering the ancient course of the River Derwent.

Charcoal concentrations increase markedly at approximately the same time as the regional rise in alder (zone D-8 of the regional profile, Figure 3.3). This may partly be a factor of the shallowing lake, as at many sites, these high charcoal concentrations often include a number of relatively large pieces of charcoal, which are probably locally derived. Plants of open habitat, e.g. goosefoot and nettle also occur, as well as light-demanding tree species such as ash. Between c. 7000-6500 ^{14}C yr BP, lime immigrated into the woodland (Birks 1989), and in a few places reached significant population levels, e.g. at Barry's Island. Fenland dominated by alder continued to cover the lake area and at No Name Hill there seems to have been the development of alder carr with wet heath.

The elm decline has not been confidently detected due to deteriorating pollen preservation levels however pre elm decline clearances appear to have occurred at Flixton Island (AK87, Innes 1994, Simmons *et al* submitted) and Profile D.

10.5.2 Final-early Mesolithic and Later Mesolithic Human Occupation

There were abundant final-early Mesolithic and Later Mesolithic sites situated around the ancient lake and upon its islands (Figure 10.5). Final-early Mesolithic sites occur during and just after the regional rise in hazel (latter half of LPAZ zone-6). Charcoal levels indicate that more than one occupation phase often occurs in relatively quick succession (within a couple of hundred years, e.g. at NAZ). Rather surprisingly this is not illustrated very well in the Regional Profile (Figure 3.5).

Later Mesolithic flint scatters occur stratigraphically higher than the early Mesolithic flint scatters due to the progressive rise of the lake and peat levels. The finds are also less concentrated, occurring over a wider stratigraphic level. The course of the new River Hertford is likely to have formed during the later Mesolithic, when most of the lake had infilled. This would then also have been an important factor affecting the location of later Mesolithic activity.

10.5.3 Final-early Mesolithic and Later Mesolithic Human Impact

Once stands of hazel began to colonise the land at around 9000 ^{14}C yr BP the degree of human impact becomes more noticeable. Charcoal Phase 3 from Flixton School, Phase 1 from NM, and Phase 3 from NAQ and NAZ all probably relate to periods of human impact in the terminal early Mesolithic.

The evidence for Later Mesolithic vegetation disturbance comes mainly from No Name Hill (Phases 2-4 at NM). Occupation during Phase 4 at Flixton School also probably occurs at the start of the Later Mesolithic, but pollen preservation conditions preclude any analyses of the processes involved. Later Mesolithic human impact is of the customary kind: charcoal peaks and some disturbance of vegetation e.g. hazel, allowing more ruderal representation. *"It adds little to our knowledge of that culture although it provokes the speculation as to whether these were separate groups from those living on the uplands or whether this was a stage in a yearly cycle of resource-use"* (Simmons *et al* submitted).

10.5.3.1 Timing, Nature and Location of final-early Mesolithic and later Mesolithic Human Impacts

The regional charcoal curve indicates continuous occupation right through the later Mesolithic. The vegetational impact of human activity seems to be easier to see and thus may have been larger in scale with charcoal increasing significantly around the same time as the alder rise (although not necessarily related). The same phenomenon occurs in Day's (1996a) diagram. This may denote a larger population or intensification of activities towards the end of the Mesolithic with larger-scale use of

fires. The significantly low Charcoal:pollen ratio is thought to be a product of the high pollen concentrations produced by the canopy forming stands of hazel and is therefore not a true reflection of human activity.

There was a fairly significant presence of Mesolithic peoples on or around No Name Hill occurring between c. 9075-<6000 ^{14}C yr BP, with fires either occurring at more than one locality *or* small scale fires were replaced by larger scale fires, with the charcoal signal registering on both sides of the island. In addition to the continued firing of the lake margins, growth of *Corylus avellana* was sometimes also encouraged but most of the time hazel was partially removed or disadvantaged by the human activities at No Name Hill e.g. at NAQ and zones NM-6 and NM-7. It seems likely from the limited evidence present, that the woodland was opened up to promote the growth of lakeside vegetation such as sedges. This negative effect on the hazel canopy demonstrates that not all human disturbance in the later Mesolithic is linked with increases in the abundance of hazel. Instead, the maintenance of productive wetland and a diverse understorey may have been just as important, as is also thought to have been the case at North Gill, North York Moors (NG7, Simmons and Innes 1996c).

Brief phases of later Mesolithic vegetation disturbance have also been detected at several other locations. At Seamer Carr disturbance at K5 in the west embayment has been dated to 8020±90 ^{14}C yr, (HAR-5789). At DI, on the south of West Island, disturbance occurs in Godwin zone VI which is probably equivalent to NM-8. There is also vegetation disturbance at M285 in Godwin's zone VI (NM-8). Finally, at Barry's Island burning of alder carr took place after 6140±60 ^{14}C yr BP, substantiated by the presence of charred alder macrofossils in the upper sediments.

10.5.3.2 Scale of Disturbance
Despite the fact that the vegetation impact of human activity seems to be easier to see and thus may have been larger in scale, most impact is relatively small. Even though associated changes to some types of vegetation are observable, these are non-proportional to the size of the charcoal peaks. Even at No Name Hill where there was a

fairly significant presence of later Mesolithic peoples, the vegetation impacts are small compared to the vegetation changes that occur in profiles from the North York Moors (Simmons and Innes 1987).

10.5.3.3 Duration

Some of the phases of final-early/later Mesolithic vegetation disturbance appear to be very brief and some last for hundreds of years although there is insufficient sampling or dating resolution to draw meaningful conclusions. At No Name Hill human occupation across the early Mesolithic to later Mesolithic boundary produces charcoal peaks with a stratigraphic span of c. 5-30 cm. Using sediment accumulation rates this would is equivalent to approximately 125-750 uncal yr. However, the resolution of the charcoal peaks is only as good as the resolution of the pollen samples. Thus, if closer sampling intervals had been employed as occurs during NM Phase 1, then the fires may be found to have occurred over much shorter time-spans.

10.5.3.4 Long-term impact?

In contrast to the evidence obtained from the North York Moors, Later Mesolithic impacts appear to have no long-term effect on the environment of the Vale, despite the repeated use of similar areas. This lack of evidence may in part be due to the lack of pollen preservation dating to the later Mesolithic within many of the pollen profiles, but may also be attributed to the differing threshold levels required to initiate environmental change. There only appears to have been a very small negative effect on the lake environment at No Name Hill prior to the alder rise. For example, only small numbers of *Succisa* and *Pteridium aquilinum,* denoting soil acidification, occur at No Name Hill in the later Mesolithic. Wet heath formation at No Name Hill was also localised, due to the paucity of evidence in the regional profile. Perhaps only in upland areas which were easily changed by pedogenic processes such as podsolisation *"did Mesolithic man exert a strong and lasting effect on his environment"* (Simmons 1975:118).

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10.6 Differences in Human Impact through Time

10.6.1 Comparison between Early Mesolithic and Upper Palaeolithic Charcoal

If the microscopic charcoal deposited during the Windermere Interstadial and Loch Lomond Stadial is derived from human activities, then this indicates that human settlers modified or subdued their fire activities in the early Mesolithic. This could possibly reflect an alteration in economic strategy instigated by cultural factors or by the changing environment. It does however, seems at odds with the change from an open landscape to a fairly closed woodland environment. A significant decrease in population seems an unlikely explanation for the reduction in fire, as population levels are thought to have been low during the late-glacial with only sporadic occupation of the Vale and the rest of Northern England (Tolan-Smith 1998; Conneller 2000). Alternatively a marked change in the abundance of charcoal deposition could indicate a complete change in the type of vegetation being burnt.

The lower charcoal concentrations in the early Mesolithic mainly reflect domestic use of fire, with only occasional firing of the reedswamp, or perhaps a change in the vegetation source of the fire? Day (1996:19) observes that, '*..the lake edge reedswamp communities at Star Carr probably burned rapidly, releasing little energy, so that most of the charcoal was deposited within a few tens of metres of the site*'. This may help explain the change in charcoal deposition patterns. Assuming population levels were not significantly higher in the pre-Holocene and that most of the charcoal is derived from human based activities and not naturally produced, the following scenario may then have occurred: In the Late Upper Palaeolithic large scale fires were lit to drive game towards the lake or into pits or the path of waiting hunters. These fires were over large enough areas or occurred frequently over a large enough time to register a significant fire signal in the lake centre. At the beginning of the post-glacial the semi-wooded environment and its associated, more solitary fauna, required a change in hunting tactics and subsequently most charcoal is derived from purely domestic or lake edge fires, which register a smaller regional charcoal signal, or alternative strategies discussed below.

10.6.2 Early Mesolithic Fires

Even though there is little impact on the actual woodland canopy, a significant factor of early Mesolithic occupation seems to be the repeated burning of the lake edges. Deliberate vegetation disturbance by fire or other means implies that *"Mesolithic communities were engaged in the deliberate manipulation of vegetation patterns as part of an organised land use strategy"* (Simmons *et al* 1989). This may not be surprising as if deliberate land use strategies were in place during the Later Mesolithic [as suggested by e.g. Simmons (1975), Simmons *et al* (1989) and Jacobi *et al* (1976)], as they may have developed gradually during the preceding period. Thus in the early Mesolithic one may expect to find a sort of precursor strategy occurring, although maybe at a smaller scale. If the manipulation of wetland vegetation *is actually* part of a deliberate land use strategy, then the detail obtained from fine resolution studies such as this, will enable us to increase our understanding of the early Mesolithic land use by establishing the character of each disturbance.

The identification of a systematic land management strategy, e.g. reedswamp burning in the early Mesolithic, would indicate that early hunter-gatherers were involved in *'specially focused, labour-demanding and ecologically interventionist activities'* (Harris 1989:20). Such practices would be classed as plant food management by Zvelebil (1994). The key point that needs to be established is: were the early Mesolithic wetland fires an early pre-requisite form of management which formed the basis of the slightly later and more widespread forms of later Mesolithic forest utilisation and management? Or were the early Mesolithic wetland fires merely accidental with most charcoal derived from domestic fires?

The sheer number of early Mesolithic wetland fires documented from the Vale of Pickering, associated either directly or indirectly with archaeological remains, suggests some form of environmental management. Even if the wetland fires were accidental in the beginning, after very few accidents the short-term benefits of burning the reedswamp would surely have been obvious and deliberate management would have been a simple progression. After all, highly sophisticated systems of wild plant

use exist or have existed within hunter-gatherer societies e.g. in North America (Harris 1977; Lewis 1982) and it would be naïve to think that our early Mesolithic ancestors were not capable of similar things.

10.6.3 Later Mesolithic Fires

At the end of the early Mesolithic and the start of the later Mesolithic, the majority of profiles (this volume) show large and distinctive charcoal peaks after c. 9000 ^{14}C yr BP. This suggests that later Mesolithic activity was either more intensive or occurred on a larger scale. However, a lack of contemporary charcoal peaks in the regional profiles (Profile D and Day 1996a) indicates that the fires still had only a localised effect. Perhaps fires were larger and/or burnt for longer but charcoal was still derived from mainly domestic fires and low intensity burning of low stature vegetation.

10.6.4 Different Scales of Impact

There appears to be a different scale of environmental impact between sites from the early Mesolithic and the later Mesolithic. Fine resolution pollen and charcoal studies are required to detect human occupation in the early Mesolithic, as this is a period of rapidly changing climate and vegetation conditions. Despite the presence of charcoal even some of the fine resolution changes in pollen are attributed to small fluctuations in the regional climate and pollen production (Human Impact Test-3, this volume). Despite the fact that some of the pollen changes in the early Mesolithic are statistically significant (Human Impact Tests 2 and 3), any human impact is likely to have been small-scale and localised. Results from a core (NM) taken just 200 m to the south of the profile from No Name Hill shows no charcoal deposition during the early Mesolithic, thus any fire impact must have been very localised not registering at a distance of 200 m away. In contrast, later Mesolithic human activity registers larger changes in pollen data and charcoal particles can be detected at distances of 200 m or more, although apparently not as far as 400-800 m away.

It may be coincidental but it is only once significant stands of hazel had become established that the degree of human impact becomes more noticeable. At No Name

Hill for instance hazel was cleared (NM Phase 1) or coppiced (NAZ, Phase 3), resulting in larger impacts on the pollen profile. Without being environmentally deterministic, this might imply that some factor coincident with the arrival of hazel initiated a slight adaptation/change in the behaviour and/or economic strategy of the hunter-gather groups. It is conceivable that the dense stands of hazel, despite providing a valuable supply of carbohydrate in the form of nuts, also reduced visibility, access to the lake edges and general all round freedom of movement around the lake edges. Clearance of hazel with or without fire would explain the declines in *Corylus avellana* in the pollen diagrams. Similarly, coppicing hazel would provide a relatively rapid and abundant supply of resources. The same areas might then become repeatedly used because secondary woodland would be easier to clear as well as being more productive. The increasing number of fires in the later Mesolithic would then be explicable by repeated occupation of a few selected sites, and the continual effort to maintain the vegetation in a similar and productive state.

Smith (1992) postulates that by c. 9000 ^{14}C yr BP (if not before), population pressure was sufficient to cause territoriality. This date coincides with the start of more intensive charcoal deposition within the Vale. Spikins (1999) has suggested that plant resource productivity was a significant factor affecting the location of base camps. In the early Mesolithic this may not have been the most important factor governing the selection of a settlement, given the relatively unrestricted mobility of hunter-gatherers in productive environments. However, once resource pressure intensifies due to an increase in population, and territories decrease, then manipulation of the environment to create resources, especially plants that are an important source of carbohydrate, would become more important. This may also explain the increase in charcoal deposition at the early Mesolithic/later Mesolithic boundary and the repeated occupation of sites.

In the later Mesolithic management of woodlands would have taken place, because natural clearings *"are unlikely to be predictable in either the extent or type of vegetation they support ….. and will rapidly grow over"* (Spikins 1999:111). It would

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have been much easier for populations to manipulate the resources themselves rather than rely on natural supplies, that were sporadic and spatially diverse. The same argument may be applicable to the hypothesis that burning of the reedswamp in the early Mesolithic, occurred (in part) to provide predictable supplies of carbohydrate.

In reality, this intensified use of fire and clearance could have been socially determined or caused by a mixture of social and/or environmental factors. Bender (1978, cited in Brown 1997) argues that developing social relations were the dynamo of economic and therefore environmental change. Thus, at some point between the early and later Mesolithic, perceptions about woodland and clearance must have changed and then manipulation of the vegetation became *"increasingly purposive"* (Brown 1997).

Social influences may also explain the concentration of human activity around the lake edge during the early Mesolithic. Brown (1997) argues that early Mesolithic people had not made the social perception or mental leaps required to initiate large clearings. Clearings need to be relatively large (c. 1 ha in size) in order for grasses to grow successfully (Röhrig 1991, cited in Spikins 1999). Due to the absence of this 'mental leap', Brown claims that the early Mesolithic peoples centred their activities around 'natural' clearings i.e. the lake edge.

In contrast this author contends that the productive lake-edge environments meant that early Mesolithic peoples had no need to create clearings as they could centre their activities around 'natural' and very productive clearings along the lake edge. Most resources would have been readily available without recourse to extensive woodland management. Although there is no data for wetland mosaic environments equivalent to those that existed during the early post-glacial, studies of the modern landscape indicate that *"the net primary productivity and available biomass of freshwater wetlands alone is second only to that of tropical rain forests and may even exceed that of some forms of intensive agriculture"* (Nicholas 1986:268). Early post-glacial wetlands were such diverse mosaics that they may *"have been capable of supporting*

particular land–use patterns normally associated with highly mobile foragers " (Nicholas 1986:267). Controlled burning of c. 10% of the reedswamp would then provide a greater supply of carbohydrate and animal browse than a 1 ha clearing in a birch woodland, and with much less expenditure of energy.

It wasn't until later, when oak migrated into the lowlands and the woodland resources decreased even further, followed by the arrival of lime (replacing oak) and ash (which replaced hazel) that *"the lowlands would have become increasingly resource-poor "* (Spikins 1999:110). This might then have fuelled the need for extensive woodland management or even agriculture.

Chapter 11 - Wider Issues

11.0 Introduction

This chapter investigates some of the wider issues highlighted by the research, i.e. to answer research Question 8 in Chapter One. The following issues will be covered: the early expansion of alder; the *Corylus* rise; the *Alnus* rise; water level fluctuations in Lake Flixton; and the detection of human impact using pollen analysis.

11.1 The Early Expansion of Alder

In the Vale of Pickering several of the pollen sites investigated provide evidence for the late-glacial or very early Holocene presence of alder, prior to its supposed immigration into south-east England. For example, in Profile D alder pollen reaches a peak of c. 10-15% TLP&S during the middle of the early Mesolithic, dating to approximately 9600-9500 ^{14}C yr BP. Pollen evidence from near to Star Carr (Walker and Godwin 1954; Day 1996a) and macrofossil evidence from nearby Willow Garth on the Yorkshire Wolds (Bush and Flenley 1987), also allude to the possible early presence of alder in north-east Yorkshire. *Alnus* wood fragments from Willow Garth (Bush and Ellis 1987) have actually been dated to 9460±80 ^{14}C yr BP.

Some of these early occurrences of alder pollen may be attributable to wind transport of pollen grains and or erosion of older deposits. However, the very constant inputs (often >1 grain) are unlikely to be explicable by the former and are not usually associated with high minerogenic inputs or pre-Quaternary spores. In fact Tallantire (1974:533) states that *"regional transport of alder pollen, producing pollen values >1% seems unlikely even in unforested areas, so that the timing of the local appearance of alder in any abundance should be relatively easily detectable in a pollen diagram"*.

Bennett (1985, 1986, 1988a, 1988b) discusses the problems of determining the first arrival of trees using palynological data. He suggested that neither the empirical nor

rational pollen limits could define a tree's first arrival, for it *'..may be achieved at population densities too low to be detected in the pollen record'* (Bennett 1986a:523), as the empirical limit is partly an artefact both of the sampling interval and of the pollen sum employed. Chambers and Elliot (1989) suggest that repeated but low traces of alder pollen may be very significant, indicating presence *'at an unknown but not necessarily extensively long distance from the sampling site'* (p546).

Pollen and macrofossils evidence found by Waller (1987) in Sussex, implies the presence of alder in Southern England by at least 10,000 ^{14}C yr BP (cited in Brown 1988:426). In addition, Scaife (1982:68) recorded the continuous deposition of alder pollen at Gatcombe Withy Bed from 9970±50 ^{14}C yr BP (SRR-1433), even though the alder rise was not until 6385±50 ^{14}C yr BP. It therefore seems unavoidable to reach the conclusion that that there were at least small populations of alder within various parts of England from very early in the Holocene, if not before. Thereafter their greater expansion was probably limited due to edaphic and/or climatic factors. For example, alder is sensitive to drought especially in the summer (McVean 1956) and so the rather hot, dry summers and cold winter conditions during the Boreal may have restricted alder expansion to sites with particularly favourable microclimatic conditions (Tallantire 1992).

Survival of *A. glutinosa* in sub-optimal lowland sites, may have occurred, so that it was able to reach parts of Britain before the traditional date of 7000 ^{14}C yr BP (Birks 1989). Chambers and Elliot (1989:541) suggest that, *"Alnus, in Britain and Ireland in the Devensian, with long-term survival of small isolated populations is not necessarily impossible........A native innoculum might have existed, and it may no longer be necessary to invoke post-glacial spread from the continent"*.

It has also been suggested that there were sheltered 'refugia' of *A. glutinosa* in the Irish Sea (Chambers and Elliot 1989) or in the North Sea plain (Moore 1986b) after all, *"floodplains are also important refugia and migration routes during Interglacials"* (Brown 1988:427). Alder's prediliction for wetland and riverine sites also means that

"the influence of beaver may have been of critical importance" in its survival (Birks 1989:548). Alternatively there may have been a presence of *Alnus* c.f. *incana* (grey alder) during the late glacial and perhaps early Holocene rather than *A. glutinosa* (see also Heyworth *et al* 1985), which would explain why the population expansion of *A. glutinosa* did not occur till later at most sites. Similar explanations (to those presented above) may be evoked for the early presence of *Quercus, Ulmus* and *Corylus* populations, as repeated occurrences of their pollen are also recorded at a number of sites prior to the rational rise of the taxa (Walker and Godwin 1954; Day 1996a; Profile D, this volume).

The fact that the peak in alder in profile D (Chapter 3, zone D-5b), is not mirrored in any of the lake edge deposits is perhaps surprising as values of 10-15% TLP suggest alder was dominant within the catchment (Huntley and Birks 1983). Nonetheless this may be due to a real but local expansion of the tree along the valley bottom of an incoming spring or stream. The identification of such a brief phase of tree expansion in the lake edge profiles would be heavily dependant on fortuitous sampling and the correct sample resolution. Alternatively, contamination of the pollen samples with modern pollen rain cannot be entirely discounted as alder has been found in Malaysian samples prepared at the same Durham laboratory (Kamaludin Hassan *pers com.*).

11.2 The Corylus Rise

These extremely rapid and early increases to high levels of hazel pollen are a striking feature of early Holocene diagrams from North-western Europe. Following an initial paper by A. G. Smith (1970), firing of the vegetation by humans as a force behind the *Corylus* rise has been discussed at length in the literature (e.g. Smith 1984; Edwards 1990; Bennett *et al* 1990b; Huntley 1993; Cummins 1994;). In the Vale of Pickering, although charcoal deposition is relatively high in (zone D-5c, Chapter Three), it not seen as a causal factor in the regional initiation of the *Corylus* rise or a cause for its prolonging. The same conclusions were reached when each of the profiles presented in this thesis, were studied individually. Likewise, Edwards (1990) found no causal

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relationship between charcoal frequencies and the *Corylus* rise from a variety of sites in Scotland. This has also been the conclusion of other authors, (e.g. Bennett *et al* 1990b, Cummins 1994).

In some profiles from the Vale of Pickering and the surrounding region later Mesolithic woodland disturbance does not even favour hazel, e.g. at No Name Hill and Flixton School (this volume) and at North Gill on the North York Moors (Simmons and Innes 1996a). Nethertheless, on a local scale, fire may sometimes have been important or coincidental in the distribution and abundance of hazel stands. At Moore's site 9, VPCG (Innes 1994), the hazel rise coincides with a thick charcoal layer which correlates to an increase in ruderals within the pollen diagram, e.g. *Plantago lanceolata* (ribwort plantain) and other weeds. Beneath the charcoal layer early Mesolithic flints are stratified within the peat. With the exception of NAZ and NM, no other profiles examined in this study show any relationship between fire and the *Corylus* rise and thus other causes for the rapid hazel rise must be responsible. Once again. this subject has been comprehensively covered within the literature and will not be examined again here, e.g. Huntley (1993); Smith (1970); West (1970); Linnmann (1981); Tipping (1996).

11.3 The Alder Rise

The alder rise is asynchronous in the Vale of Pickering and within Britain as a whole. The rise in alder at No Name Hill is dated to 6160±50 ^{14}C yr BP which is considerably later than the date of 7640±85 ^{14}C yr BP obtained from a core just 800 m to the south-east of No Name Hill (Day 1996a). In fact the arrival of alder at NM is approximately 1500 years later than other established dates in northern England (Huntley and Birks 1983; Smith 1984; Birks 1989). Some delay may be linked to the lag in migrating northwards around the lake edge and to the belated arrival upon the island, but even conservative estimates for migration rates should not explain this anomaly. If seed dispersal were the only constraint to alder establishment one would expect alder to arrive fairly early at No Name Hill due to its lake island location, and given its good seed dispersal.

The local expansion of alder could be due to one or a combination of factors, which may account for the asynchronous rise of alder:

   i.   disturbance by humans

   ii. a change in soil and edaphic conditions.

   iii. decreased local competition

   iv. an increase in waterlogging caused by beavers (Chambers and Price 1985)

   v.   Climate.

Human impact has often been cited as a cause for the rapid expansion of this tree (Smith 1970, 1984), as high charcoal concentrations often accompany the sharp rise in pollen values and alder is often present in small quantities prior to its expansion. Studies by Hirons and Edwards (1990) and Edwards (1990) have deduced that burning and clearance actually appears to favour the spread of alder. However, its association with human disturbance is not always as well marked as it is at Newferry (Smith 1984). In the Vale of Pickering there is an increase in the abundance of ruderals and charcoal at the transition to alder carr in several of the profiles investigated as illustrated in Table 11.1, but the results still remain inconclusive.

Table 11.1   Vegetation disturbance as a cause for the alder rise? The evidence:

Profile	Evidence	Caused by Humans ?
AK87 *	The alder rise at AK87 in zone-Ak-g occurs just before 5990±90 ^{14}C yr BP and coincides with the creation of open areas and the appearance of *Plantago lanceolata* and also a large peak in *Pteridium*.	Possibly, but mostly occurs afterwards
E77 ◆	The pollen diagram, shows that the dry land vegetation and soils and perhaps the marginal water deposits were disturbed at levels just prior to the rise in alder but no charcoal counts were undertaken.	Possibly
Flixton 1035 *	The alder rise at Flixton 1035 occurs at approximately 6815±110 ^{14}C yr BP (Hv-17827) Pollen indicates a	No Evidence

Profile	Evidence	Caused by Humans ?
Flixton 1035*	regional but not local alder population. Consequently there is no convincing evidence for contemporary vegetation disturbance.	No Evidence
CVIII ◆	The Alder rise is coincident with a black charcoal layer and a decrease in pine. The presence of Caryophyllaceae, *Artemisia*, Compositae Liguliflorae and Compitae Tubuliflorae, suggest some disturbance of the ground vegetation.	Possibly
D3	The charcoal curve at D3 increases coeval with the start of the alder rise (undated). Pollen levels indicate regional alder with some local encroachment. but there is no contemporaneous increase in herb diversity.	Probably Not
NM	The alder rise occurs at No Name Hill just before 6160 ± 50 ^{14}C yr BP. There appears to be evidence for disturbance of the vegetation but this is not coeval with the alder rise.	Probably Not
VPCG *	Pollen preservation deteriorates before this level	?
LAP	The beginning of the alder rise is truncated	?
NAQ	Pollen preservation deteriorates before this level	?
NAZ	Pollen preservation deteriorates before this level	?
LAL	The beginning of the alder rise is truncated	?

* source: Innes (1994) and Simmons *et al* (submitted) ◆ source: Cloutman (1988b)

At Bonfield Gill and North Gill on the North York Moors, Simmons and Innes (1981, 1988) state that whilst alder is a beneficiary of woodland disturbance, it is not the only one. Perhaps then, the rise in alder is mainly caused by other factors and human disturbance is just an added dimension, which obscures the main causes of the tree establishment and is seized upon by palynologists who are unable to separate these other factors within the pollen record. After all, *"Charcoal will inevitably occur at*

archaeological sites, such as Newferry (Smith 1984), and will often be associated in time with some degree of vegetation change because of the rapidity and frequency of early post-glacial vegetation change" (Bennett *et al* 1990b:639). These factors would also explain the observations of Bennett *et al* (1990b:639). They state that, *"Anthropogenic burning can only have caused the regional increase of alder if the effect was on a landscape scale. The different patterns of temporal changes of charcoal abundance at Hockham and Quidenham suggest that no such widespread burning was taking place".*

Even if human disturbance was a contributing factor, the (rather late) expansion of alder at Flixton AK87 and No Name Hill, cannot be solely attributable to human disturbance, as both sites show evidence for small populations of alder prior to the main population rise. There also appears to have been significant periods of later Mesolithic human activity at both sites in this preceding 1500 year period.

The most likely reason for the asynchronous rise in alder is soil development, substrate stability, nutrient status and soil type (Brown 1988). Most evidence points to a change in soil status, e.g. at AK87 increasing soil acidity and waterlogging causes an increase in *Sphagnum* (Innes 1994). At the same time peaks in *Pteridium* and *Calluna* point to the local encroachment of dry land and altogether this indicates the initial favourable conditions for alder expansion. Although of course the alder rise may also be dependant on a number of other conditions potentially including human disturbance. Other factors which might be partly responsible are: competition from willow or pine (Brown 1988) or the presence of beavers which may have aided its spread (Chambers and Elliott 1989). However, soil development and type are likely to be most important factors (Brown 1988). Alder is likely to have been locally present from an early date, e.g. c. 9600 ^{14}C yr BP (see section 11.1), but was out competed probably by hazel and or willow until alder was eventually favoured by edaphic changes.

The true reason for a sudden but asynchronous rise in alder both locally, regionally and nationally, may lie in a complex and indistinguishable interaction of climate,

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disturbance and soil edaphic factors. "Disturbance or burning of catchments leads to increased runoff of water, causing greater erosion and nutrient flushing in the basins, all of which would favour alder" (Moore 1986b:204). Moore suggests that burning of reedswamp itself could supply alder with the opportunity for invasion as Thompson and Shay (1985) have demonstrated that burning of reedswamp leads to the growth of shorter (but denser) and less robust reed shoots. Palaeoecological evidence from the Vale of Pickering (this volume) and Star Carr (Day 1993, Day and Mellars 1994, Mellars and Dark 1998), suggests that reedswamp burning can be associated with the activities of human groups from very early within the Holocene (i.e. 9650 ^{14}C yr BP). Thus, prior to c. 7500 ^{14}C yr BP climatic conditions prevented alder from competing effectively with other tree taxa, so it was unable to take full advantage of any areas of disturbance, and prior to this time soil conditions were unfavourable within most areas of the catchment anyway. However, as soil and climatic conditions became more favourable small alder populations started to expand around the encroaching lake, human groups may have initiated further burning of reedswamps and alder, to reverse the hydrosere progression and increase productivity within the lake. This would have been in a bid to keep the lake edge open, as it was the foci of animals and thus an important source of food and also vegetable resources (Mellars and Dark 1998:181).

At LAP on Barry's Island, burning of alder carr is known to have occurred, but has been dated to after 6140±60 ^{14}C yr BP, substantiated by the presence of charred alder macrofossils in the upper sediments. Unfortunately, *"the felling of alder leads to vegetative sprouting and cloning which could result in its rapid spread in swamp forests"* (Moore 1986b:204). Therefore, despite possibly trying to delay the formation of alder carr, human groups may have unintentionally aided and hastened its spread.

However were human groups really that ignorant of ecological conditions? Alternatively when burning did occur, it may have been coincidental to the spread of alder, i.e. humans may have advantageously utilized hazel (perhaps through coppicing), and thus alder was provided with the opportunity to expand. Once alder had expanded the climate and soil conditions were now suitable and it was then able to compete with hazel.

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The alder rise may also just be coincidental with the deposition of charcoal from domestic fires. In areas where human activity was absent or non-intensive, alder carr would have developed naturally, with carr becoming established at a time when soil, climatic and competitive conditions proved favorable.

The rapid increase in alder pollen is also likely to be linked to the high pollen outputs of the tree. Percentages of 25-90% TLP indicate the formation of *in situ* alder carr, thus the rapid increase in alder pollen at the alder rise probably reflects the formation of carr at each individual sampling site and also explains the difference in timing between different catchments or regions. The sediment profile at No Name Hill probably documents the *in situ* arrival of alder at an area very near the deepest water, consequently, suitable soil conditions may well have taken much longer to develop. There does appear to be an increase in herb diversity i.e. human related disturbance, after the transition to alder carr at NM, but there is no evidence for any preceding or contemporaneous increase. In contrast, the site of Day's (1996a) core (Figure 3.1) may have received regional inputs of alder pollen and macrofossils from a much earlier date. Equally, although there is no immediate local hydrosere in profile D (Chapter 3), the lake is encroaching at the start of the alder rise and the sampling site is probably receiving alder pollen from both local and regional sources which may confuse the issue.

11.4 Fluctuating Water Levels

The analysis of contemporaneous water levels throughout the lake unit is problematic due to the differing locations of the pollen profiles in relation to the lake-shore. This results in great variations in local vegetation with contrasting pollen source areas, differing rates of hydrosere development and depositional environments. The level of information provided by each author also varies restricting some types of analysis, e.g. pollen preservation. As a consequence correlation between profiles is often

problematic and sometimes results in conflicting conclusions. However, some broad trends have been identified using the data here, and these are discussed below.

After the Windermere Interglacial lake levels fell, indicated by the presence of *Pediastrum* peaks in most of the relevant cores from around the lake. According to Cloutman (1988a) the lake levels during the late-glacial stadial (Younger Dryas) stood at less than or equal to 23 m OD. A low water level is also illustrated by the fact that the lake was seasonally frozen *"permitting the disturbance of the lower calcareous mud by freezing and thawing at this time..."* (Walker and Godwin 1954:36). These lower lake levels may have been particularly marked during the second half of the Younger Dryas when the climate was drier and "it is likely that most precipitation fell as snow" (Isarin *et al* 1998:451). Greater aridity in the second half of the Younger Dryas is also indicated by an increase in aeolian activity in the Vale (Day 1996a; Innes 1994). The very end of the Loch Lomond Stadial must then have been succeeded by a period of higher water levels because at LAP the sedimentary sequence recommences at the start of the pre-Boreal. A similar rise in water level has been observed at PCC and QAA along the southern lake edges (Cummins 2000b, 2001) and elsewhere in the lake (Walker and Godwin 1954). The layer of *Sphagnum* peat at LAP demonstrates that the water level in the lake was approximately 22.90 m OD at 10,140±100 ^{14}C yr BP. Consequently, the late-glacial water levels must have been even lower.

Slightly later, at the start of the post-glacial (c. 9700 ^{14}C yr BP), the water level at Star Carr stood at c.23.4 m OD, deduced from the stratigraphy in Trench A (Mellars and Dark 1998:26). This compares well with the higher levels of c. 24 m OD proposed for the early Holocene by Cloutman (1988a). A few hundred years later, during the middle of the early Mesolithic, Walker and Godwin (1954:69) proposed that there was another rise in the lake level, when the outlet at the western end of the lake silted up. Cloutman (1988a) also proposes higher lake levels in the early Holocene, with levels at c. 25 m OD by c. 9500-9000 ^{14}C yr BP. The evidence from LAP (Barry's Island) and Star Carr certainly points to a slight rise (0.5 m) during the very early part of the post-glacial. At NAQ there may have been a short-term rise in the water level

(possibly dating to c. 9500 BP), but if it did occur it was very short term and probably lasted less than 100 years.

Most cores analysed in this study, e.g. NAQ, FS and Profile D, exhibit small fluctuations in aquatic taxa, e.g. *Nymphaea alba, Sphagnum* and *Pediastrum*, which provide some limited evidence for fluctuations between wetter and drier conditions during the first millennia of the post-glacial (Bohncke and Vandenberghe 1991). However, all of the profiles investigated here show no convincing evidence for a unidirectional rise in the lake levels during the latter half of the early Mesolithic, with most stratigraphic changes merely attributed to local hydrosere progression. This may however, be a function of the water depth at the sampling point and the degree of water level fluctuation. For example, the water at the sampling spot may have been too deep to register a very slight rise in water level.

During the later Mesolithic, at approximately 8250 ^{14}C yr BP (NM-8) there appears to have been a change in the hydrological zone at No Name Hill (NM), resulting in a decrease in lake level or change in the precipitation/evaporation ratio. This resulted in the formation of seasonally dry sedge carr with high proportions of ferns and sedges. Dry conditions at c. 8000 ^{14}C yr BP have also been suggested for other parts of the UK and Ireland due to hiatuses in deposits in eastern England, the Lake District and eastern Ireland (cited in Tallantire 1992). At Hockham Mere the most severe conditions occurred between 7800-7500 ^{14}C yr BP, while Rybnîcek and Rybnîckova (1987) cite seasonal droughts elsewhere in Europe over the same periods. Further analysis and additional dating of the sediments around the lake is required before these periods can be interpreted as a time of regionally drier climatic conditions throughout the Vale of Pickering. Although acording to Cloutman (1988a), lake levels also fall at the Boreal/Atlantic transition c. 7500 BP, something that is also seen at Flixton 1 (Walker and Godwin 1954:55-6).

A mineral layer at LAP dated to 6700±890 yr before 1998, indicates another phase of lowered lake levels, which allowed the palaeo-Coulton Beck to flow over the peat on

Barry's Island. This was followed sometime later c. 6600 ^{14}C yr BP (allowing for potential errors with the radiocarbon dates), by a rise in water level at NM, as the pollen preservation curve indicates a drop in pollen deterioration between 26-7 cm (top NM-7b-NM-8). This coincides with the first appearance of *Alnus* in the profile. There is also evidence for a rise in lake level at Seamer Carr (Cloutman 1988b) around this time when carr was replaced by reedswamp. This event has been dated to around 6500 ^{14}C yr BP (Cloutman 1988b), a date which is not inconsistent with the evidence from No Name Hill. Walker and Godwin (1954:69) also suggest a slowly rising water table in the Atlantic caused by rising sea level and blockage of the lake overflow. This is substantiated by evidence for better pollen preservation in zone LAP-8 at Barry's Island, which also suggests a rise in water level during the Atlantic (i.e. < 6700±890 yr before 1998).

11.5 Detection of Human Impact using Pollen Analysis

11.5.1 Is it viable in a large lake?

As the vegetation mosaics around Lake Flixton are small in comparison to the catchment area, there was a possibility that the vegetation reconstructions from this large lake would appear homogenous, when in reality the vegetation was highly heterogeneous (Sugita 1994:881). However, despite the distance from the early Mesolithic shoreline, the pollen profiles show up observable differences between the vegetation communities at the different locations. This is because the sediment profiles from the lake edges are near enough to be influenced by local and extra-local pollen inputs and it explains why the lake edge pollen diagrams often differ from the regional pollen diagram. The differing charcoal curves also provide further qualification that charcoal deposition throughout the lake edges is very localised, with the lake centre/regional profiles obtaining charcoal from both the aerial catchment as well as charcoal inputs from the lake-edge occupations. This also provides a validation for the research project, showing that it is realistic to look for localised human impact in lake-edge sediments from a lake of this size.

11.5.2 Is the detection of human impact feasible?

Human-induced patterning of the vegetation is likely to be very complex and difficult to be clearly identified from the pollen record. This is likely to be true even for the fine resolution studies from the lake-edges, as the pollen deposition is still averaged over more than 1 year (with the exception of pollen records compiled from varves). There is a need for more research into the generation, deposition and taphonomy of charcoal at the lake edges, as at the present time, the estimated duration of human settlement is only as good as the resolution of the sediments themselves. Consequently many fires may have occurred within the stratigraphic span of a single pollen sample.

Local vegetation changes and the processes involved in these changes are also unlikely to be identifiable, unless the sediments are derived from within the immediate area (less than 30 m). Even then, it is still unclear to what extent floristic diversity in clearance episodes is of a natural origin or the result of ecosystem disturbance by human populations (see Section 10.1.2). The pollen diagrams and archaeological activity also need to be securely dated, with the pollen diagram reconstructed from sediments of the same date (preferably directly from the archaeological site or very near by). Then and only then, can the vegetation changes be definitely associated with human activity.

The preceding statements do not mean to imply that fine resolution pollen analyses are a waste of time as… *"To point out the problems is to pave the way to solutions, not to destroy the validity of the method"* Williams, C (1985:28). However, random pollen analysis of sediments from areas with no inter-calated archaeology or where the pollen source area is not extremely local, is unlikely to be very informative or provide information about changes to the vegetation or prevailing economic strategies of prehistoric human groups.

Pollen analysis can however be used as a tool to indicate areas of occupation, and highlight new and potentially rich areas for the archaeologists to excavate. For example during the present study the pollen profile from No Name Hill indicated that

there was little early Mesolithic occupation along the southern shore of the island and that excavations might be more forthcoming if they were concentrated along the northern edge of the island. Similarly, analysis of the profile from Flixton School suggested that there was considerable human activity occurring nearby. Flixton School has since been found to occupy a very large area of the former lake-shore (>90 m). Nonetheless, these initial pollen profiles should be considered to be 'test profiles' or 'preliminary profiles', as non-detection of human disturbance is unlikely for anything other than the *"most fortuitously located profiles"* (Edwards 1983:143). The charcoal signal could also be very weak or perhaps undetectable. This is because most locally occurring charcoal is deposited within c. 80-100 m of the fire, and generally not more than 400 m (from Rhodes 1996; Day 1996a; Moore 1999; profiles NM, NAZ and NAQ, this volume). In addition, the relative location of the sampling site in relation to the foci of settlement also changes over time, and this may obscure much of the vital information.

11.5.3 Improved methods for the detection of human impact in pollen profiles

Absolute dating of any archaeological phases relating to a pollen profile is a necessity in order to be able to directly attribute the vegetation changes to human activity. The problems of directly dating episodes of human activity are discussed in Housley (1998).

Once the potential episode of human activity has been identified, then identification of macroscopic charcoal (>32,000 μm^2) to species using SEM techniques, ought to be routinely utilized. This is a major criticism of the present study, as although sporadic occurrences of charcoal have been identified to species, no systematic analyses were undertaken. Hathers (1998) work from Star Carr demonstrates just how useful this technique can be, as not only is the charcoal identifiable to family or even species, but the season of the fire event is sometimes also distinguishable, e.g. *Populus* catkins were burnt during April/May (late spring/early summer).

The results of this thesis suggest that a two-stage archaeological excavation plan would be beneficial whenever possible. Firstly the sites would be excavated and preliminary pollen cores analysed to assess the preservation of the sediments, the number of occupations and their relative proximity to the pollen sequence, bearing in mind the progression of the hydrosere. Secondly, once the archaeological layers have been identified, new pollen samples should be obtained, which would be ideally positioned as near to the occupation site as possible for a specific time period. Ideally, once all the archaeological artifacts have been analysed and interpreted it would then be desirable to go back to the pollen profiles to look for new ways to verify or falsify any new theories. Using such an approach, palynology may be able to provide the answers to vital research questions which may help to convert even the most sceptical of archaeologists.

The results of this present study are considered to have been limited by the fact that the palynological work had to go ahead whilst the archaeological excavations were unfinished and often only in their preliminary stages. Concentration on a single site, e.g. No Name Hill, using a number of profiles at varying distances and spatial locations from the excavations, would also have been beneficial.

Chapter 12—Conclusions

Star Carr was just one of numerous early Mesolithic sites located around the edge of Lake Flixton and upon the lake islands. Before this study began, it was expected that the new analyses from Flixton School, No Name Hill and Barry's Island, would either replicate or provide the same level of detailed palaeoecological information that had been obtained from Star Carr (Day 1993; Day and Mellars 1994; Mellars and Dark 1998). However, the three new sites presented here, serve to demonstrate the uniqueness of Star Carr, in terms of organic preservation and thus, level of obtainable information. Regardless of these limitations, the present study also serves to highlight the variability in environment, location, type and intensity of human impact that existed in the eastern Vale of Pickering during the late-glacial and earliest post-glacial.

In brief, the conclusions of the study are as follows:

12.1 Upper Palaeolithic

During the Upper Palaeolithic and to a lesser extent during the Pre-Boreal, fires were widespread over large areas of the catchment. Microscopic charcoal records from different areas of the catchment, bear remarkable differences as well as similarities, suggesting that fires were localised as well as regional in occurrence. The exact reason or origin for these fires is unknown. The high association between charcoal and sand (Nichols *et al* 1997) and a lack of knowledge about the prevailing climate means that the peaks in charcoal cannot be reliably attributed to human activity. Consequently the fires are tentatively attributed to a combination of factors of varying importance, e.g. Upper Palaeolithic human hunting activities, climatic fire events and secondary deposition of older charcoal. As human populations within the Vale were low during the Late Upper Palaeolithic, the latter two factors are thought to be most important.

12.2 Early Mesolithic

The three-stage test for human impact applied to two of the new sites at Flixton School and No Name Hill, has (in part), enabled the determination of significant periods of human impact. However, Human Impact Test 3 has only been limited in its use, due to the short time period when the model is applicable, and the use of only linear regression curves. Fine resolution analyses of the regional profile have also shown that levels of herb, shrub and disturbance pollen are an artefact of the sampling resolution. Closer interval sampling produces more of these pollen types, even in a profile reflecting the natural undisturbed environment. In addition, small changes to herb and shrub pollen, which are often taken to be the result of human activity, cannot be subject to statistical analysis as their values are too small.

However, during the earliest part of the Mesolithic Human Impact Test 3 has enabled natural or background variations in pollen output (IV+BV) to be taken into account. Test 3 confirms that periods of significant human impact are still observable at the two sites mentioned above. Due to poor pollen preservation in the early Mesolithic sediments at the third site of Barry's Island, it has been impossible to determine whether humans had an impact on the vegetation of the island.

The conclusions from the analyses of early Mesolithic Human Impact are:

The early Mesolithic sites varied in function, location, environment, type and intensity of human impact

The archaeological and palaeoecological information retrieved from the Vale of Pickering over the last 50 years, (including the three sites presented here), demonstrate the variability amongst the sites discovered to date. All the sites differ in terms of densities and type of finds and thus function and type of occupation. It is now clear that hunter-gather societies exhibit considerable variation in environmental perceptions, mobility, spatial utilisation, social, economic and seasonal approaches and thus no single interpretative model is likely to fit all archaeological manifestations.

Occupation of the archaeological sites generally occurred over decades rather than years

The deposition of microscopic charcoal occurs over a fairly wide stratigraphic width (usually >1 cm) and so by inference, the fires occurred over a number of years. Further research into charcoal deposition and taphonomy is however required, along with precise dating of archaeological phases, in order to elucidate the real duration of fires and occupation phases. As at present, the duration of human settlement is only as good as the resolution of the sediments themselves, e.g. within a single pollen/charcoal sample, many fires may have occurred.

There may have been synchronous occupation of the lake system

Human occupation of different parts of the Vale occurred during very similar (although not necessarily contemporary) time periods, e.g. Phase 2 at Flixton School (c.9000-9200 ^{14}C yr BP) and Site C on East Island (9260±90 ^{14}C yr BP) are statistically indistinguishable (Cloutman 1988b).

The presence of a radiocarbon plateau at c. 9650 ^{14}C yr BP (Day and Mellars 1994) and consequently, the lack of absolute radiocarbon dates within this study, have limited the establishment of an accurate chronology of occupation. Despite this, a relative but approximate chronology has been established (using the *Dryopteris filix-mas* curve). This suggests that Phase 1 at Flixton School probably occurred at the same time (if not a little before) the first phase of occupation at Star Carr. Phase 1 along the north side of No Name Hill is also possibly contemporary with the second phase of occupation at Star Carr.

Occupation appears to have taken place within a very narrow vegetative zone as indicated by flint scatters

In particular, the human activities are thought to have occurred within the (seasonally dry?) reedbeds at the margins of the lake. The high concentrations of flints deposited within this zone are thought to be linked to hunting activities, as animals would be attracted to the lush vegetation in these 'natural clearings'

Site locations were repeatedly occupied

The location of an occupation or hunting area was probably determined by various

economic, ecological and social reasons, as Mesolithic occupation would have occurred within a socially constructed landscape (Ingold 1986). Human populations in and around ancient Lake Flixton would have had access to a stable, predictable and diverse range of ecosystems either immediately or by exchange. This is perhaps why it could have formed an almost 'persistent place in the landscape' since the earliest lake formation.

Disturbance was small scale and localised

The dissimilar charcoal records from sites within the Vale of Pickering suggests that the majority of the microscopic charcoal originated from local sources, i.e. less than 250 m away. With the exception of Star Carr, where woodland removal occurs (Day 1993), the sites show little or no disturbance to the woodland canopy. Disturbance of the woodland understorey of ferns, and the reedswamp is more visible and occurs at all sites. However, this disturbance is still 'apparently' small-scale. Perhaps the palaeoenvironmental record is reflecting human activity at light intensity exploitation camps, where human activities were brief and narrowly focused?

These results are perhaps not surprising as, "*A great deal depends on the sensitivity of the ecosystem to human exploitation and the degree to which this is reflected in the pollen analytical signal.*" (Walker and Singh 1993:104). "*Perhaps we should not expect anything but the most extreme impacts to be ......clearly recorded*".

At some sites a specific wetland exploitation strategy may have been in use

Microscopic reed and rush charcoal has been identified at almost all the early Mesolithic sites studied here, (with the exception of Barry's Island). Thus. burning of the lake edge vegetation did not occur solely at Star Carr. This could be entirely coincidental and caused by the accidental spread of fire, but a deliberate wetland exploitation strategy is just as likely, e.g. managing plant resources or as an aid to hunting.

Our understanding of the human use of fire during these occupation phases would be enhanced by more detailed analysis of charcoal concentration results and macrofossil remains. In addition, faunal and lithic analyses of the same sites would

increase our understanding of the way the sites were utilised and aid our interpretation of the palaeoenvironmental data. More detailed inspection of the pollen and charcoal curves at Flixton School are also required to identify the subtle inter-relations of the climate, water level fluctuations and human activity.

Woodland disturbance was most intensive at Star Carr

Human impact is much more noticeable and intense at Star Carr but this may partly be attributable to the relative locations of the sampling points in relation to the prehistoric activity areas. At Star Carr monolith MI (Mellars and Dark 1998) was just 10 m from the early Mesolithic shoreline whereas most of the monoliths in this study were >20 m from the contemporary shoreline at c. 9600 ^{14}C yr BP. In addition, at Star Carr (Mellars and Dark 1998), three monoliths were analysed, taken at progressive distances from the shoreline. This is in contrast to the single monoliths examined for most of the present study sites. This was due to time constraints and the number of sites which had to be investigated.

However, Star Carr is still the earliest absolutely dated site to be discovered so far, and to exhibit significant environmental disturbance caused by human occupation. In all probability larger areas of reedswamp and woodland were affected by the activities of human groups at Star Carr than elsewhere. This may be due to the size and or nature of the settlement site, as the concentration of finds and extent of finds are generally higher at Star Carr than elsewhere.

Star Carr is unique

So far, Star Carr appears to be unique, in terms of the density and variety of faunal and lithic remains, although recovery of archaeological artefacts has been biased at other sites, due to the poor levels of preservation, e.g. VP88D and Flixton School Field. Even so, Star Carr contained the largest assemblage of barbed points in the world, with only a couple of barbed points found elsewhere in the Vale. The site also contained the earliest evidence for split-planked wood in the world, despite abundant evidence for beaver activity in the form of felled trees. In addition, there were also, lots of stone axes, contrasting with the paucity of axes from elsewhere in the Vale. For example, only one other axe has been found in the Vale, at No Name Hill, although several flint chips have been found at other sites.

Ever since Star Carr was first published in 1954, the use of the site has been the focus of much discussion and numerous re-interpretations (see Chapter One). More recently, Schadla-Hall *et al* (in prep) have interpreted Star Carr as a ritual/ceremonial site, located on the outlet of Lake Flixton and perhaps used for hunting ceremonies over a very long period of time. This would explain the abundance of barbed points and the presence of antler head-dresses. By contrast, the other sites in the Vale were thought to be more temporary and narrowly focused.

12.3 Later Mesolithic

Vegetation Disturbance was more intensive

Disturbance of the vegetation either became more intensive during the Later Mesolithic or took place on a larger scale. At the start of the later Mesolithic, the majority of profiles (this volume) show large and distinctive charcoal peaks after c. 9000–8600 ^{14}C yr BP. This suggests that later Mesolithic activity was either more intensive or occurred on a larger scale. However, a lack of contemporary charcoal peaks in the regional profiles (Profile D and Day 1996a) indicates that the fires still had only a localised effect. Perhaps fires were larger or burnt for longer but charcoal was still derived from low intensity fires or from burning of low stature vegetation.

Moreover, early Mesolithic vegetation disturbance can only usually be detected using very close interval sampling, whereas in contrast, later Mesolithic human activity registers large changes in pollen data and charcoal can be detected at distances of 200 m or more.

Later Mesolithic disturbance in the uplands of the North York Moors was still much more intense than any disturbance in the lowland Vale of Pickering. Evidence from the Vale of Pickering shows no long-term large-scale impacts on the vegetation even during the later Mesolithic. Perhaps only in upland areas which were easily changed by pedogenic processes such as podsolisation *"did Mesolithic man exert a strong and lasting effect on his environment"* (Simmons 1975:118).

12.4 Summary

Although it has not been possible to answer in full all the questions that were posed at the beginning of this study (see Chapter One), the study has still succeeded in gathering important information which will add to our knowledge of these important and under documented periods of pre-history. The timing of the study appears to have been crucial as although the preservation of organic material within the sediments is patchy, the results of the study show that the oxidised peat has reached a critical depth within the archaeological deposits. In light of the results from Star Carr and the three sites studied here, it is perhaps unfortunate that archaeological excavation and detailed palaeoecological analyses were not carried out some 20-40 years earlier, following the discovery of Star Carr and its adjacent sites. In the future, more detailed examination of both pieces of work ought to help to interpret the relationship between Star Carr and the other early Mesolithic sites in the eastern Vale of Pickering.

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